DOCUMENT RESUME

ED 302 420 SE 050 258

TITLE	Computers in Life Science Education. Volume 5, 1988.
INSTITUTION	National Resource for Computers in Life Science Education, Seattle, WA.
PUB DATE	88
NOTE	97p.
AVAILABLE FROM	National Resource for Computers in Life Science Education, Mail Stop RC-70, University of Washington, Seattle, WA 98195 (Subscription $40.00).
PUB TYPE	Collected Works - Serials (022)
JOURNAL CIT	Computers in Life Science Education; v5 n1-12 Jan-Dec 1988
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Biological Sciences; *College Science; Computer Assisted Instruction; *Computer Uses in Education; Courseware; Higher Education; Instructional Improvement; Microcomputers; *Newsletters; Science Education; *Science Instruction; Secondary Education; *Secondary School Science; Simulation; Teaching Methods

ABSTRACT

Designed to serve as a means of communication among life science educators who anticipate or are currently using microcomputers as an educational tool, this volume of newsletters provides background information and practical suggestions on computer use. Over 80 articles are included. Topic areas include: (1) using a personal computer in a plant physiology course; (2) annual report and directory; (3) Apple workstations; (4) hypercard; (5) expert systems; (6) computer graphics for simulations; (7) the use of computer simulations to reinforce laboratory experiences; (8) Stella simulation software; (9) software evaluation; and (10) authoring systems. Also provided are guidelines for the preparation and submission of articles to the newsletter, subscription information, indexes for each volume, and lists of meetings and synopses. "Where's the Software?" and "Keeping Abreast of the Literature" are periodic feature articles. (CW)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED302420

VOLUME 5 NUMBER 1, JANUARY 1988

CLSEE3 5(1)1-8, 1988 ISSN 0742-3233

COMPUTERS IN LIFE SCIENCE EDUCATION

HAROLD I. MODELL
Department of Radiology
University of Washington
Seattle, Washington

MARCEL BLANCHAER
Department of Biochemistry
Faculty of Medicine
University of Manitoba
Winnipeg, Manitoba

THEODORE J. CROVELLO
Graduate Studies and Research
California State University, Los Angeles
Los Angeles, California

JAMES W. ECKBLAD
Department of Biology
Luther College
Decorah, Iowa

TSEGAYE HABTEMARIAM
School of Veterinary Medicine
Tuskegee University
Tuskegee, Alabama

DONNA LARSON
School of Nursing
Grand Valley State College
Allendale, Michigan

TERRY M. MIKITEN
Graduate School of Biomedical Sciences
University of Texas Health Science Center
San Antonio, Texas

JAMES E. RANDALL
Department of Physiology
Indiana University
Bloomington, Indiana

PATRICIA SCHWIRIAN
College of Nursing
Ohio State University
Columbus, Ohio

RICHARD STULL
College of Pharmacy
University of Arkansas
Little Rock, Arkansas

JAMES W. WOODS
Lister Hill National Center
for Biomedical Communications
National Library of Medicine
Bethesda, Maryland

DOROTHY WOOLEY-McKAY
Department of Biology
Glendale Community College
Glendale, Arizona

GLEN YOSHIDA
Department of Life Sciences
Los Angeles Southwest College
Los Angeles, California

NRCLSE

"PERMISSION TO REPRODUCE THIS
MATERIAL IN MICROFICHE ONLY
HAS BEEN GRANTED BY
Harold I Modell
TO THE EDUCATIONAL RESOURCES
INFORMATION CENTER (ERIC)."

CONTENTS

FIRST STEPS USING PERSONAL COMPUTERS IN A PLANT PHYSIOLOGY COURSE 1
Larry Blakely

DIAGNOSTIC PRACTICE REINFORCES LESSONS FROM LABORATORIES 5
Nils S. Peterson, Stephen A. Feiner
and David D. Barbee

FIRST STEPS USING PERSONAL COMPUTERS IN A PLANT PHYSIOLOGY COURSE

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvem
EDUCATIONAL RESOURCES INFORMAT
CENTER (ERIC)

☐ This document has been reproduced
received from the person or organiza
originating it

☐ Minor changes have been made to impr
reproduction quality

- Points of view or opinions stated in this d
ment do not necessarily represent off
OERI position or policy

Larry Blakely
Biological Sciences Department, California State Polytechnic University, Pomona, California

I have been enamored of the microcomputer since the days (ancient history!) of the Osborne 1, my first micro. The microcomputer gradually became *the* indispensible tool for my research and teaching in plant physiology. I used the old ozzie (I called it "Porky" in honor of its oinky-sounding disk drives) for obvious things like writing up lecture notes for class distribution, class handouts, and for keeping grades. I started to write tutorials (not very effective on Porky) and to dream about hooking up Porky to lab equipment, but then came the IBM-PC: goodbye CP/M, hello color.

Microcomputers clearly promise to make instruction in beginning and advanced plant physiology courses more effective and more stimulating to students. All that is needed is the equipment, the time to get it all together and to write programs, and a lot of imagination – a mighty tall order. A NSF grant to a group of several members of our department, including me, made it possible for me to make a start. I now had an XT with a 10 Mb hard disk permanently available in the teaching lab, plus 1 to 3 others that I could [illegible], along with an A/D board and a digitizing tablet. Time to quit dreaming and

0742-3233/88/$0.00 + 2.00

SE 050 258

BEST COPY AVAILABLE

get started.

Since we began, the beginning one-quarter course in plant physiology has been given twice. The following sections describe the major modifications made in the course to utilize microcomputers.

LABORATORY DATA ACQUISITION AND ANALYSIS

I modified four laboratory exercises to utilize microcomputers for data acquisition (via either the serial port or an internal A/D board) and data analysis. I also wrote simple user interfaces in BASIC. The four laboratories dealt with transpiration, leaf temperatures, CO_2 uptake in photosynthesis and measuring pH changes in chloroplast suspension.

Transpiration

In an exercise that I have used for several years, students measure the rate of transpiration of 2-week-old bean seedlings employing a weighing method. Data are collected on the effects of an anti-transpirant chemical and on the effects of light versus darkness. The plants that are used have two expanded leaves and are growing in a small pot. The total weight of each potted plant is less than 100 g (this is important because of the limited capacity of the top-loading mg balance that is used).

Prior to taking transpiration rate measurements, the pots are sealed with tape to prevent water loss from the soil, and any growth above the two expanded leaves is severed. Thus, essentially all water loss is through the two leaves. The students determine the transpiration rate in units of mmol water lost per m^2 of leaf area per second.

In previous years, leaf area was determined by weighing cut-out paper leaf tracings that were then compared to the weight of 0.01 m^2 piece of the same paper. The rate of water loss was determined from weight measurements made at the beginning and end of a 30 minute period.

Because of the time necesary for students to gain an accurate understanding of the written instructions once in the lab setting, and for actually carrying out the required steps of the experiment, it was necessary in the past to assign different treatments to different student teams. Each team posted its results on a blackboard at the end of the period, and at the next lab period, all students copied all data and prepared a report.

I realized that using microcomputers could improve the efficiency of this exercise in several ways. Data collection and computations could be substantially automated, prompts from the computer could keep the students on track, and final data reports could be accurately prepared. Summary and interpretation of data, done outside of the lab period, would still be the student's responsibility. With the increased efficiency, I found that *each* team could collect a set of data on *all* variables. Class data were still combined for statistical analysis. The latest implementation of this exercise utilizing microcomputers is outlined below.

Equipment. Two stations were set up, each with an IBM PC (with color monitor and one floppy disk drive), a printer, and a top-loading mg balance connected to the PC via the serial port. A large cardboard wind deflector was placed around the balance so that air currents would not influence plant weight measurement.

For light conditions, three high intensity lamps were set up under which plants were placed when not being weighed. A small side room was used for dark conditions.

A digitizing tablet, attached to another PC, was set up at another station. The students had learned how to use the digitizing tablet for measuring leaf area in a previous exercise.

Software. I wrote a QuickBASIC program to prompt the students for data entry and to print data reports. This program ran continously on the computers at the weighing stations. Sigmascan, a commercial software package for use with the digitizing tablet, was used for determining leaf areas in m^2.

Protocol. Each team of 2 students used 2 plants, one of which they treated with an anti-transpirant chemical. The area of the 2 leaves on each plant was determined with the digitizer. After a period of adaptation under the lamps, the plants were taken to a weighing station for the initial check-in. In response to prompts from the computer, the team members entered their team number, names, leaf areas of their plants, and the name of the anti-transpirant they used. They were then instructed to place each plant, in turn, on the balance. The computer recorded the weight from the balance and time from the computer's system clock. The program then stored the data in a disk file, using the students' team number and the day's date (read from the system clock) for the file name (for example, A50187.DAT, for team A5). The students then placed their two plants back under the lamps.

After 10 to 15 minutes in the light following the first weighing, and when their weighing station computer was free, the team returned with the plants for a second weighing. The plants were next dark-adapted for a few minutes, and then weighings were made at the beginning and end of 10-20 minutes in the dark. During each session with the computer at their weighing station, the student team's file was opened and updated with the new weight and time data.

After making the final weighing, the team requested a report of the results from the weighing station computer. The report included all the data they had entered (names, leaf areas, and leaf resistances that they measured with a Li-Cor autoporometer) and the calculated transpiration rates of each plant in light and dark, based on weight, time, and leaf area data. A report of all class data was subsequently prepared (it included a statistical analysis of the data) and given to each student.

Results. The use of microcomputers enabled this lab execise to run more smoothly than in previous years, and each team obtained more data. The students were impressed with the capabilities of the computer and appeared to take the exercise more seriously than in the past.

Leaf temperatures

I have run a demonstration exercise on the effects of radiation, wind speed,

0742-3233/88/$0.00 + 2.00

and other factors on leaf temperature. One small thermocouple is pressed against the lower surface of a leaf, while another shielded thermocouple is used for air temperature. In the past, readings from both thermocouples were recorded on a two-pen chart recorder. I decided to use the microcomputer for this exercise.

An IBM PC with a Metra-Byte A/D board (model Dash-8/Exp-16) was used in place of the chart recorder. Thermocouples were attached directly to the Exp-16.

In the first implementation of the computerized version of this exercise, I used Labtech-Notebook Software. For the second, I wrote a BASICA program, that was easier to use and set up. In each case, a run-time graph of temperatures was displayed on the computer screen.

Leaf and air temperatures were recorded under various conditions of radiation and wind and saved in an ASCII file. A screen dump of the computer screen on-line graph, or a graph produced after the data was imported into Lotus 1-2-3, was given to each student for inclusion in his or her report on the demonstration. Graphing the data on the screen using Lotus provided an "instant replay" of the temperature records.

The data was easier for the assembled class to see from the computer screen display than from the chart recorder used in the past. The ability to re-run a graph of the temperature versus time data using Lotus made reviewing the results more dynamic. Furthermore, setting up the demonstration is easier using the computer than using the chart recorder.

Photosynthesis – CO_2 uptake

For several years, I have used an exercise in which students make measurements of the rate of photosynthesis using an infra-red gas analyzer and the CO_2 depletion method. Briefly, a leaf is placed in a small plastic box under lights. A 10 ml sample of gas is extracted from the box with a syringe, and, after 1 to 4 minutes, another gas sample is extracted. The gas samples are injected into CO_2-free air passing through the sample port of the infra-red gas analyzer. The CO_2 content of each sample is determined, and the difference between the two calculated. Based on the volume of the box, the change in CO_2 content, the area of the leaf, and the elapsed time between sample extractions, the photosynthesis rate can be calculated in micromols of CO_2 taken up per m^2 per second.

I modified the exercise to include data acquisition by a microcomputer. In the past, students took data from a chart recorder tracing, a process that was time consuming, prone to error, and required a calibration and conversion from chart paper units to ppm CO_2. Use of the microcomputer promised to eliminate these problems. I did decide, however, to leave final calculation of photosynthesis rates up to the students. In the future, I will provide a program that will allow students to confirm their calculations, but still not do it for them!

The infra-red gas analyzer was connected to a Metra-byte A/D board (model Dash-8/Exp 16) on an IBM PC. CO_2-free air flowed through both the sample and reference ports of the infra-red gas analyzer. Students injected 10 ml samples of air into the air flowing into the sample port.

A digitizing tablet attached to another microcomputer was also set out. This was used for leaf area determination (as noted above, the students had learned to use it in earlier exercises).

I wrote a BASICA program that used a simple user interface to accept data, carry out calibration calculations, and determine the CO_2 content of samples.

One or more students were enlisted to inject calibration gases for the calibration procedure. Each student team was then instructed to obtain a sample of outdoor air for CO_2 content determination. (I had them do this mainly to help reinforce classroom discussions of the CO_2 greenhouse effect, and implications for plants in the future. We're keeping a year to year database of the results.) Each team then obtained CO_2 measurements for photosynthesis determinations at 2 or 3 different light intensities. Finally, the CO_2 compensation point of a particular species was determined by each team.

Use of the A/D board and the microcomputer gave students the CO_2 concentration immediately after sample gas injection, helping to maintain their interest.

Photosynthesis - pH change in chloroplast suspensions

As part of an exercise on the light reactions of photosynthesis using suspensions of isolated chloroplasts, I conduct a demonstration on change of the bathing solution pH upon illumination (an apparent result of proton uptake into the chloroplast thylakoids). In the past, I used a chart recorder attached to a sensitive pH meter to record changes in pH. I have now switched to using a microcomputer and an A/D board in place of the chart recorder. The benefits of using the microcomputer in this exercise are similar to those mentioned above in the case of the exercise on leaf temperatures.

LAB DATABASES

For several of the lab exercises used in this course, I ask the students to gather and analyze all of the data obtained by the whole class. In some cases, this is so that class averages, rather than just one data set, may be used for drawing conclusions. For example, in the case of the effect of auxin on the number of adventitious roots formed on cuttings, there is considerable variation from student team to student team. In other cases, this is done to expand the number of species sampled. For example, in determinations of the frequency (number per area) of stomates on leaf surfaces, different teams are asked to make counts on different species.

In the past, I had the students post their team's data on the board, and when all data have been posted, all class members were asked to copy all of the data for use in preparing reports.

I now use Lotus 1-2-3 custom worksheets for this purpose. Student teams enter their data, and when all class data has been entered, each student has the computer print a summary. Lotus macros were used to make friendlier user interfaces for the worksheets. I will accumulate data from year to year for certain databases, for example, the stomate frequency versus plan species database.

0742-3233/88/$0.00 + 2.00

TUTORIALS

I have written five BASICA microcomputer turtorials to go with this course. They are available on the hard disk of the plant physiology lab PC and also in the computer lab at the University's library. Students may also copy these onto their own personal disks, if they desire.

I plan to write additional tutorials in the future as time allows using BASIC or other formats such as Show Partner. The latter promises to make tutorial writing a much easier and more rewarding task, although I have just begun to explore its use.

The five tutorials include the following.

- Hangperson, a word game designed to foster familiarity with plant physiology terminology.
- Transpiration Rate Tutorial, based on mathematical models of plant transpiration, allows students to enter various parameters (such as wind speed, air humidity, and leaf resistance) to see how they would affect the transpiration rate.
- Spectrum, a tutorial to familiarize students with the spectrum of visible light, providing drill in equating colors with corresponding wavelength ranges.
- Hit the Reaction Center, a graphics representation of photon capture, energy transfer, and flourescence in the light reactions of photosynthesis.
- The Calvin Cycle, a tutorial designed to give the student a familiarity with the overall process of carbon dioxide fixation in photosynthesis and to gain familiarity with the major intermediate substances involved.

ADVANCED PLANT PHYSIOLOGY

I used our microcomputers extensively during the most recent offering of my one quarter course called Advanced Plant Physiology. The students, who are generally well motivated, are expected to carry out more involved lab projects with less direction than is the case in the beginning course. I decided to have the students use Lotus 1-2-3 extensively for data handling and graphing, as I have found it very useful for these purposes in my research.

I introduced the students to this spreadsheet software during the first week. I taught them the rudiments of data entry and graphing and encouraged them to study the software manual to increase their expertise in using the package. In the various exercises they performed in subsequent weeks, they became adept at using Lotus 1-2-3 for data handling and analysis and for preparing tables of data and graphs for their reports. Of course, the students learned how to use the Metra-Byte A/D board and the digitizing tablet for use in their lab investigations (I do all the setting-up in the beginning course).

CONCLUSIONS

Although the full potential for using microcomputers in plant physiology courses is far from being realized, the experiences described above have convinced me of the value of micros. In evaluating the course, students often mention, in a positive way, their experience with one or another of the computer applications, and they say they would have liked more. With time and the acquisition of additional equipment, the courses will surely be made more stimulating learning experiences through the use of microcomputers. I want to write more tutorials, especially interactive ones. The software tools that are available for programmers of limited sophistication (like me) are certainly adequate for writing valuable, graphics-based tutorials. It just takes a lot of patience and imagination. I also want to extend the number of lab exercises using micros for data collection and analysis. Their use should illustrate how things are done in the real world, as well as be instructional. I would like the students to be more independent in using the micros in the lab (a lot of hand-holding has been necessary so far). At some point in the future, I will require that each student provide a floppy disk on which to store a set of programs and lab data.

To anyone teaching courses like this who hasn't yet gotten into the world of microcomputers, I would heartily recommend that you do so. It will bring a new spark to your enjoyment of teaching (although expect some periods of frustration!), and it will surely enhance the educational experiences of your students. I assure you that the possibilities are so numerous that you will never, in a dozen careers, run out of new things to try in the quest for the best ways of getting your educational messages across.

The tutorials described are available free to anyone who might like to try them. They were written in BASICA for a CGA card and are GW-BASIC compatible. Please send a stamped, self-addressed mailer and a blank 5 1/4" disk to: Larry Blakely, Biological Sciences Dept, California State Polytechnic University, Pomona, CA 91768.

SUBSCRIPTION INFORMATION

Computers in Life Science Education is published monthly by National Resource for Computers in Life Science Education, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Subscription rate is $30.00 for 12 issues, including postage and handling in the United States and Canada. Add $20.00 for postage (airmail) in Mexico and Europe and $23.00 for the rest of the world.

This newsletter has been registered with the Copyright Clearance Center, Inc. Consent is given for copying of articles for personal and internal use. This consent is given on the condition that the copier pay through the Center the per-copy fee stated in the code on the first page for copying beyond that permitted by the US Copyright Law.

Address orders, changes of address, and claims for missing issues to NRCLSE, Mail Stop RC-70, Univ of Washington, Seattle, WA 98195. Claims for missing issues can be honored only up to three months for domestic addresses and six months for foreign addresses. Duplicate copies will not be sent to replace ones undelivered due to failure to notify NRCLSE of change of address.

Address editorial correspondence to Harold I. Modell, PhD, NRCLSE, Mail Stop RC-70, Univ of Washington, Seattle, WA 98195.
(BITNET MODELL@UWALOCKE)

POSTMASTER: Send address changes to *Computers in Life Science Education* NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

DIAGNOSTIC PRACTICE REINFORCES LESSONS FROM LABORATORIES

Nils S. Peterson, Stephen A. Feiner and David D. Barbee
Department of Computer and Information Science, University of Oregon, Eugene, Oregon and College of Veterinary Medicine, Washington State Unviersity, Pullman, Washington

In the past, simulations have been widely heralded as powerful learning vehicles. A large number of such models have been created. A common property of these models is interaction among a large number of system properties producing a range of responses in system variables. Instructors using these simulations have used a variety of strategies, ranging from non-directed suggestions that students "play" to prescribed "experiments" with specified data recording, reporting, and analysis. Presumably, those teachers used simulations because they felt models would help students develop an appreciation for system interactions, compensations, and limits of function. The success of that supposition remains largely conjecture. As a modeler, I know that "playing" with a model develops my "feel" for it, but does the average student play as systematically?

The goal in giving students simulations is for them to build a framework for integrating system interactions. To achieve this, the learner must focus on predicting model behavior, not watching passively. One very successful way to use a simulation is in small group discussions where the teacher asks, "If I increase this parameter, can you predict what will happen to that variable? How much? Why?" This is cause to effect reasoning. Certainly, it represents the type of mental dialog we hold with ourselves when exploring a system. Prediction requires more effort and sophistication than watching, and students are less prone to adopt it. Consequently, most students truly play with simulations rather than study the operation predictively.

Previously, we reported a study of veterinary medical students in which, after a "traditional" lecture and wet lab unit on the cardiovascular system, they still held strongly anatomic views of the cardiovascular system.[3,4] Subsequently we asked them to solve a series of "diagnostic" problems. These problems were cast as games in which one cardiovascular property from a list of 8 was disturbed randomly either up or down. After playing 50 faults, we reassessed their perceptions of the system. Their views had developed a new functional dimension, and that new dimension had shifted in the direction of an expert's understanding.

Our diagnosis game helped students pose questions that are the reciprocal of those described above. They were asking, "If this variable has changed, which properties could explain it?" This is effect to cause reasoning. Our program is called the Fault Identification Game. Like clinical experiences, the games reinforce both a functional understanding of the specific system and general problem-solving skills. This paper will show how new games can be written to compliment many other simulations.

The data representations within the game are very general. Problems can be created for any system that can be described in terms of properties (maximum 20), variables (maximum 20) and the interrelationships between them. We define "properties" as those entities that are independent variables, that is, external inputs to the simulation. Our "variables" are dependent values that arise from the interactions between properties. The game is designed to permit non-programmers to develop problem sets easily. Creating a problem requires entering data about a system into a specified format, using either a text editor or a spreadsheet. Required data are shown in Table 1.

Table 1. Data required to create a problem.

For the problem:
1. A short "presenting complaint"
2. A short closing discussion

For each property and variable:
1. Name, abbreviation, and units
2. An order describing where (and if) each will be displayed

For each property:
1. A value
2. The value's deviation from normal (+,-,0)

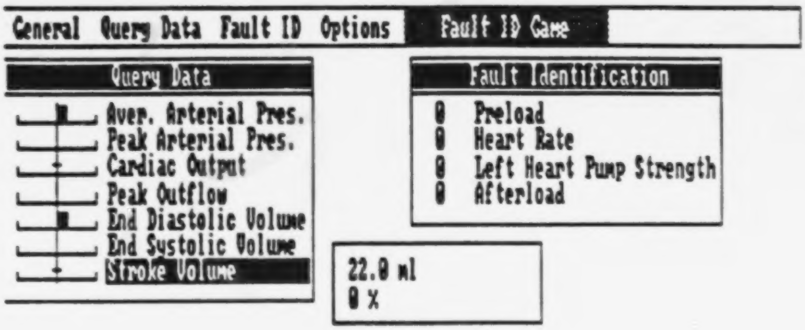
For each variable:
1. A flag describing the variable as either quantitative or qualitative
2. A deviation from normal (+,-,0), or qualitative description (eg, "missing", "open", "elevated")

AN ISOLATED HEART EXAMPLE

In the Isolated Heart preparation of the author's Cardiovascular Systems and Dynamics (CVSAD) program [4], four properties determine the performance of the heart: preload, afterload, heart rate and left heart pump state. If the values of these properties deviate from normal, the new state of the system will be reflected in values of its variables: cardiac output, stroke volume, end systolic volume, end diastolic volume, average arterial pressure, and peak arterial pressure.

In this example, one or more of the properties was changed from normal. Some of the variables are abnormal, others show no change. In Figure 1, the player has requested values of arterial pressure, cardiac output, end diastolic volume and most recently, stroke volume. The game reports SV is 22 ml and that this is normal (for a dog). Some possible faults can be eliminated and some are clearly suggested. At this point, the player begins to enter a tentative hypothesis, (Figure 2, right). A hypothesis is recorded as a

0742-3233/88/$0.00 + 2.00


General
Query Data
Fault ID
Options
Fault ID Game
Query Data
Aver. Arterial Pres.
Peak Arterial Pres.
Cardiac Output
Peak Outflow
End Diastolic Volume
End Systolic Volume
Stroke Volume
Fault Identification

0 Preload
0 Heart Rate
0 Left Heart Pump Strength
0 Afterload

22.0 ml
0 X

FIGURE 1. Querying data from the Fault Identification Game. Possible data are shown on the left. Possible faults are shown on the right.

setting (-,0,+) for each property. In this case, the diagnosis reads increased preload, decreased left heart strength, and others normal.

When a diagnosis is entered, the computer can be asked to evaluate it. In this case, the answer is partly right, as shown in Figure 2, bottom. The response is reported as a Venn diagram showing fault(s) suspected (S for suspected) by the player and fault(s) actually contained in the problem (D for disturbed). Verbal confirmation is also provided. Correct answers show perfect intersection of sets "S" and "D", partial answers show partial intersection, and wrong answers show no intersection. In this case another aspect of cardiac failure remains to be diagnosed.

AUTHORING A PROBLEM

The previous example comes from a simulation developed by the authors. It is equally possible to create problems from other simulations. It is equally possible to create problems from other simulations. It is even possible to create useful student problems from a model that is otherwise too complex for instructional purposes. The central task is phrasing the problem with only those properties and variables that are appropriate to the student's academic level. The following examples show the process of authoring a problem and some of the diversisty of material that can be encoded.

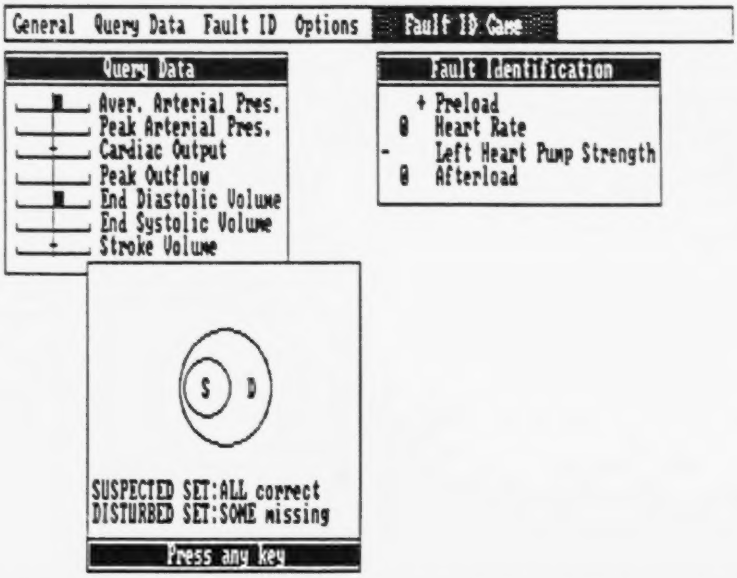
The data for a problem are stored in a compacted file format. We have given these files DOS filename extensions .SDF, for System Data File. Problem authors need not concern themselves with the organization of SDF files, rather they may fill in textual forms in either wordprocessor (ASCII) or spreadsheet (DIF) formats. In each case, a utility program converts SDF files to and from the more familiar formats. We chose wordprocessors and spreadsheets as simple interfaces faculty already have experience using. Further, they provide a potential hardware independent link for transferring faults from one computer to another because the SDF format is machine dependent.

Encoding a clinical example with a wordprocessor

In *Pulmonary Pathophysiology*, West[5] describes clinical observations for a variety of respiratory diseases. A fault problem can be written. from his description of restrictive disease (Chapter 5),

"Spirometry typically reveals a restrictive pattern. The VC [Vital Capacity] is markedly reduced, but the gas is exhaled so rapidly that although the FEV$_{1.0}$ [Forced Expiratory Volume in 1 second] is low, the FEV/FVC% [Forced Vital Capacity] may exceed the normal value. The square shape of the forced expiratory spirogram is in striking contrast to the obstructive pattern. The MMFR [Maximum Mid-Expiratory Flow Rate] is normal or high. The flow volume curve does not show the scooped out shape of obstructive disease, and the flow rate is often higher than normal when related to absolute lung volume."[5]

"The arterial Po_2 and Pco_2 are typically reduced and the pH is normal.


General
Query Data
Fault ID
Options
Fault ID Game
Query Data
Aver. Arterial Pres.
Peak Arterial Pres.
Cardiac Output
Peak Outflow
End Diastolic Volume
End Systolic Volume
Stroke Volume
Fault Identification
S
D
Press any key

+ Preload
0 Heart Rate
- Left Heart Pump Strength
0 Afterload

SUSPECTED SET:ALL correct
DISTURBED SET:SOME missing

FIGURE 2. Checking a diagnosis. The diagnosis is entered at the top left as high preload, low heart strength, others normal. The computer says the answer is partly correct, but something(s) is still missing.

0742-3233/88/$0.00 + 2.00

Table 2. Data extracted from problem in West's *Pulmonary Pathophysiology*

Variable name	Value	Units	% from normal
Forced Vital Capacity	2.9800	liters	-38
Forced Exp Vol - 1 Sec	2.8800	liters	-30
$FEV_{1.0}/FVC$	0.9700	unitless	13
Max Midexpiratory Flow	4.7600	l/sec	6
Peak Expir Flow	5.0000	l/sec	-50

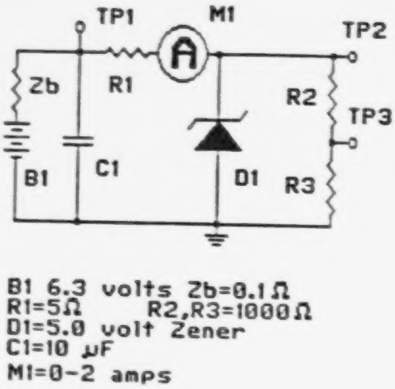


FIGURE 3. Circuit diagram for an electric circuit model that was developed in a spreadsheet and then had its data exported to FIG game datasets.

The hypoxemia is usually mild at rest until the disease is advanced. However, on exercise the Po_2 often falls dramatically and cyanosis may be evident."[5]

The data in Table 2 were extracted from this description. These constitute the variables for the problem. The "faults" can be encoded in one of two ways. One set would focus on the clinical description such as restrictive disease or obstructive disease. Alternately, the fault could be encoded in terms of defects in functional entities such as lung compliance and airway resistance.

Note that not all the diagnostic information mentioned by West was used. The data selected are at the discretion of the problem's designer. However, adequate data must be present to distinguish this fault from others in the same problem set.

Table 3. Encoding properties and variables in a wordprocessor

```
|<<variable 1>>|
Forced Vital Capacity |<name>|
FVC|<abbr>|
1|<active var?>| 1=yes, make active in this
                 game
1|<index>|       place data in cell 1 of
                 display
-38|<dev>|
liters|<units>|
0|<binary var?!  0=no, its not binary data
1|<display value?>| 1=yes, display data in
                    the problem
2.9800|<value>|

|<<property 1>>|
Compliance|<name>|
Compl|<abbr>|
1|<active prop?>| 1=yes, show it in this
                  game
1|<index>|        place this fault in
                  display      position 1
-1|<qual value>|  this property is below
                  normal
0|<binary prop?>| 0=no, its not binary
0.0000|<value>|   actual value is unknown
                  from West's text, but it
                  won't be shown in that
                  game, so its  not
                  necessary
```

Table 3 shows how the data from Table 2 are entered into the wordprocessor template generated by the Fault Game's utility. One data item is entered to the left of the descriptions marked in single angle brackets. Double bracketed terms indicate a division within the data record and have no data associated with them. After entering all the data into this file, it is processed back into the compact SDF used by the game.

Programming a model into a spreadsheet

Perhaps the most powerful method of entering data is via a spreadsheet capable of writing DIF (Data Interchange Format) files. Most spreadsheet programs have this capacity. In this example, Twin (Mosaic Software), a "work alike" of Lotus 1-2-3, was used. A file called FIGPLATE.WKS, provided with the game, is a blank template to be filled with author's data. The critical parts of the sheet are protected to prevent inadvertent corruption of the format.

The equations for the model were entered into the bottom of the sheet. All the functions and indirect referencing features of the spreadsheet were used to relate the various properties and variables. This master model can be saved to disk and reloaded. Faults are created by altering desired properties and letting the model in the spreadsheet recalculate the variables. Just a few key strokes are required to modify the sheet and save the data for a new problem.

To augment a course in electronic troubleshooting, a circuit model was developed using the schematic in Figure 3. Nine properties were used: battery internal impedance, capacitor (dc) impedance, resistors R-1, R-2 and R-3, diode impedance, D1, battery voltage, and the total impedance of the external circuit. A portion of the spreadsheet (Table 4) shows the layout.

In building the model, some properties, such as resistances and voltages, were direct analogs of the physical component they represented. The functional impedance of the zener diode, however, was quite complex. A reverse biased zener diode exhibits high impedance (nearly an open circuit) until the zener voltage is reached. From then on, it shows a voltage dependent impedance that maintains the voltage drop across the diode at exactly the zener voltage. Using the logical @IF function of the spreadsheet, these two possibilities were modeled. When the fault prevented the voltage at TP2 from exceeding 5.0 volts, the diode impedance was 1010 ohms (used for open circuits), otherwise an impedance was calculated based on current flow in the circuit to provide zener action. Variables presented to the student were limited to the voltages present at the test points (relative to ground) and the current in Meter M1. Resistance measurements could easily have been allowed, but the design goal for the model was to teach active, in-circuit troubleshooting.

The model used rather complex formulas to compute the variables. For

0742-3233/88/$0.00 + 2.00

example, the Test Point 1 voltage was computed from the battery voltage (Ebatt), the external system impedance (Rs), and the internal or battery impedance (Rb) using the following formulas.

Total current(Itotal) = Ebatt/(Rs + Rb))
Voltage of Test Point 1 = Itotal * Rs.

In the normal circuit, the calculated voltage was 6.2743 volts. Faults were either shorts (R=0) or opens (R= 1010 ohms) in the resistors, except for the battery impedance which was merely increased to simulate a "weak" battery condition. Only single fault sets were used in this case, but multiple faults could be used. A further refinement would be to add ratings, such as power, to some components. The spreadsheet could then evaluate to see if the instructor induced fault caused an overload somewhere else that "took out" additional components.

CUSTOM VERSUS GENERIC FAULT GAMES

Boyle and Robinson described an acid-base balance game.[1] In this program the student sees a graphical display showing arterial P_{CO_2}, plasma bicarbonate (HCO_3^-), and pH. The normal range, blood buffer line and current patient status are displayed graphically and in tabular form. The player is asked to determine the most appropriate diagnosis for the given acid-base state. The screen then presents a list of diagnoses that represents all combinations of primary and compensatoy acid-base states. After a correct diagnosis is selected, the player can select treatment options. These include defining values for respiratory rate and tidal volume and ordering an infusion of acid or basic solution over a 60-minute interval to adjust base excess or deficit. The patient's status is altered on the display during the course of therapy. Tutoring is provided for misdiagnoses and improper therapies.

Boyle and Robinson's fault finding game is a custom application for acid-base balance. The game described here is generic. Acid-base problems could be implemented in the generic engine, but they would lose the graphical interface and the tutorial feedback of the custom version. On the other hand, custom programs require new programming for each application. Our goal was to develop an engine sufficiently flexible that non-programmers could use it to create problem-solving exercises in a wide variety of domains with little instructor time investment.

AVAILABILITY OF THE PROGRAM

A preliminary version of the program for the IBM PC is available. The program uses the UCSD P-system and has sample problems along with student and faculty manuals on disk. These may be obtained by sending a blank floppy disk and self addressed envelope (a diskette mailer is best) to the authors. An improved version, used to illustrate this article is being prepared for publication. Problem sets created for the initial version will be fully compatible with the new one.

Table 4. Encoding a problem in a spreadsheet

<<PROPERTIES>>			
	<property 1>	<property 2>	<property 3>
<name>	Battery	Impedance C1	Limit Resistor
<abbr>	Zbatt	Zcap-1	R-1
<active prop?>	1	1	1
<index>	1	2	3
<qual value>	0	0	0
<binary prop>	0	0	0
<value>	0.10000	10000000.0000	5
<<VARIABLES>>			
	<variable 1>	<variable 2>	<variable 3>
<name>	Test Point 1	Test Point 2	Test Point 3
<abbr>	E-TP1	TP-2	TP-3
<active var?>	1	1	1
<index>	1	2	3
<dev>	0	0	0
<units>	Volts	Volts	Volts
<binary var?>	1	1	1
<display value?>	1	1	1
<value>	6.2743	4.9899	2.4950

This work was supported by grants from US Department of Education (FIPSE) #G008440474 and National Institutes of Health HLBI (SBIR) #1R43HL37790.

REFERENCES

1. Boyle, Joseph III and Gloria Robinson. Acid-base balance: An educational computer game. BioScience 37(7):511-513, 1987.
2. Hopkins, RH, KB Campbell, and NS Peterson. Representations of perceived relations among the properties and variables of a complex system. IEEE Trans Sys. Man and Cyber. SMC-17(1),52-60, 1987.
3. Peterson, NS, KB Campbell, RH Hopkins, and SA Feiner. An integrated cardiovascular teaching laboratory. The Physiologist 28:447-448, 1985.
4. Peterson, NS and KB Campbell. Teaching cardiovascular integrations with computer laboratories. The Physiologist 28:159-169, 1985.
5. West, John B. Pulmonary Pathophysiology, 2nd ed. Williams and Wilkins, Baltimore, MD., 1982, p. 98.

VOLUME 5 NUMBER 2, FEBRUARY 1988
CLSEE3 5(1)9-16, 1988 ISSN 0742-3233

COMPUTERS
IN LIFE
SCIENCE
EDUCATION

HAROLD I. MODELL
Department of Radiology
University of Washington
Seattle, Washington

MARCEL BLANCHAER
Department of Biochemistry
Faculty of Medicine
University of Manitoba
Winnipeg, Manitoba

THEODORE J. CROVELLO
Graduate Studies and Research
California State University, Los Angeles
Los Angeles, California

JAMES W. ECKBLAD
Department of Biology
Luther College
Decorah, Iowa

TSEGAYE HABTEMARIAM
School of Veterinary Medicine
Tuskegee University
Tuskegee, Alabama

DONNA LARSON
School of Nursing
Grand Valley State College
Allendale, Michigan

TERRY M. MIKITEN
Graduate School of Biomedical Sciences
University of Texas Health Science Center
San Antonio, Texas

JAMES E. RANDALL
Department of Physiology
Indiana University
Bloomington, Indiana

PATRICIA SCHWIRIAN
College of Nursing
Ohio State University
Columbus, Ohio

RICHARD STULL
College of Pharmacy
University of Arkansas
Little Rock, Arkansas

JAMES W. WOODS
Lister Hill National Center
for Biomedical Communications
National Library of Medicine
Bethesda, Maryland

DOROTHY WOOLEY-McKAY
Department of Biology
Glendale Community College
Glendale, Arizona

GLEN YOSHIDA
Department of Life Sciences
Los Angeles Southwest College
Los Angeles, California

NRCLSE

CONTENTS

NRCLSE ANNUAL REPORT FOR 1987 9

CLSE 1987-88 COLLEAGUE DIRECTORY – PART I 11

NRCLSE ANNUAL REPORT FOR 1987

The overall purpose of NRCLSE is to cultivate collaborative efforts among faculty with expertise in using computers in life science education. The broad goal of the Resource is fourfold:

1) to educate faculty in effective uses of computers in the curriculum;
2) to promote research aimed at evaluating new applications of the computer to life science education;
3) to promote development of a critical mass of high quality, versatile software; and
4) to serve in a consultant capacity for life science faculty currently active or interested in becoming active in this area.

This year's activities were focused on further establishing the Resource as a viable entity capable of serving the life science community. A statement of NRCLSE's financial status is presented in Table 1.

GENERAL OVERVIEW OF ACTIVITIES

In 1987, NRCLSE applied for and received non-profit [501(c)(3)] status from the Internal Revenue Service. In addition to making us eligible to receive tax deductible donations, the IRS approval of our non-profit status makes us eligible to apply to various foundations and funding agencies for support of specific projects. We have begun a process to identify foundations whose interest areas include use of computers in life science education as an initial step in developing future projects.

Publication of Computers in Life Science Education continues to be our primary activity. However, during the past year, we have continued our software development project in respiratory physiology, provided information to colleagues throughout the world concerning use of computers in life science curricula, participated in regional and national meetings, and

0742-3233/88/$0.00 + 2.00

conducted demonstrations and workshops at a number of institutions.

Computers in Life Science Education

Subscriptions to CLSE continue at the same level as in previous years, with close to half of the subscriptions being held by libraries. The geographic distribution of subscribers continues to grow. Distribution now includes subscribers in 10 countries representing 4 continents.

In addition to our regular features, "Keeping Abreast of the Literature" and "Where's the Software?", we have begun publishing an annual colleague directory of life science educators interested in using or actively using the computer as a teaching tool. The intent in providing this information is to help life science educators establish links with potential colleagues. Entries for the directory have been drawn primarily from responses to the NRCLSE questionnaires published in CLSE.

Software development

Work on conversion of our Apple II package of simulations (Simulations in Physiology - The Respiratory System) to MS-DOS and Macintosh formats continued during this year. All three packages are now complete and available for distribution. Appropriate announcements and purchase information for each set was included in Computers in Life Science Education when each set was completed.

Resource Information

During 1987, NRCLSE responded to over 75 requests for information concerning use of the computer as an educational tool. The majority of these concerned suitable software for use in the laboratory setting.

The geographic origin of the requests indicates that we are beginning to accomplish our goal of providing widespread service. Requests originated from institutions in Australia, Belgium, Canada, Denmark, England, Italy, Jamaica, Mexico, Spain, Sweden, and the UnitedStates (24 states, the District of Columbia, the U.S. Virgin Islands, and Puerto Rico).

Table 1. NRCLSE Financial Report for year ending December, 1987.

Fund Balance, December 31, 1986		**$14,928**
Revenues		
Cash donations	845	
Equipment donations	0	
Subscriptions	5,080	
Software sales	2,008	
Total Revenues	7,933	
Expenses		
CLSE production	4,182	
Operating supplies	2,102	
Contractual services	2,258	
Travel	567	
Software purchases	141	
Total Expenses	9,250	
Fund balance, December 31, 1987		**$13,612**

Presentations/Consultation

Personnel from NRCLSE organized or participated in symposia, panels, and workshops at 5 regional and national meetings during the year. Workshops and demonstrations were also presented at two universities. Topics included teaching problem-solving in physiology, the computer as a teaching aid in biological sciences, the role of the computer in the lecture hall, future trends in physiology teaching, and computer applications other than traditional computer-aided instruction in health science education.

Establishing a peer critique mechanism for software

In 1987, we began our effort to establish a peer critique mechanism for reviewing software by initiating a dialog on the topic in Computers in Life Science Education. This effort will continue in 1988 with our first goal being to establish criteria for such a mechanism. To get as much input as possible before establishing specific criteria, we will survey other groups already involved in peer review of software, and the two articles published in CLSE will be reprinted in Science Software, a quarterly publication serving the science community.

SPECIAL THANKS

NRCLSE extends a very special "Thank you" to the following people, organizations, and institutions for their support in 1987.

American Institute of Biological Sciences
730 11th Street, N.W.
Washington, D.C. 2001-4584

Dr. Joel Michael
Department of Physiology
Rush Medical College
Chicago, IL 60612

Paula Olcott
6768 48th Ave. S.W.
Seattle, WA 98136

University of Washington
Seattle, WA 98195

Zenith Data Systems
300 120th Ave.
Bldg. 1, Suite 205
Bellevue, WA 98005

CLSE 1987-88 COLLEAGUE DIRECTORY – PART I

The primary goal of the National Resource for Computers in Life Science Education (NRCLSE) is to cultivate collaborative efforts among life science faculty interested in using the computer as a teaching tool.

The directory that follows is updated from the 1986-87 directory and was drawn primarily from respondents to questionnaires printed in CLSE. It is intended to help readers identify colleagues with common interest areas.

The listings are arranged by the content areas identified in response to the question, "What content areas do you teach?" As a result, entries may appear under more than one heading.

Although every attempt has been made to ensure that the information is current and correct, it is likely that some errors appear in this list. We apologize in advance for any inconveniences that may arise due to such oversights. Part II of the directory will appear next month.

If you are aware of other colleagues that should be listed, please send their names, addresses, phone numbers, and teaching content areas to NRCLSE, Mail Stop RC-70, Univ. of Washington, Seattle, WA 98195 or let us know via BITNET. NRCLSE's BITNET address is MODELL@UWALOCKE.

AGRONOMY

ARNESON, PHIL A
DEPT OF PLANT PATHOLOGY
CORNELL UNIV
ITHACA, NY 14853
(607) 255-7871

DAVIS, THOMAS M
DEPTS OF PLANT SCIENCE
AND GENETICS
UNIV OF NEW HAMPSHIRE
DURHAM, NH 03824-3597
(603) 862-3217

ESTES, DR GEORGE O
DEPT OF PLANT SCIENCE
UNIV OF NEW HAMPSHIRE
DURHAM, NH 03824
(603) 862-3220

HELSEL, ZANE R
DEPT OF AGRONOMY
UNIV OF MISSOURI
COLUMBIA, MO 65211
(314) 882-2001

ANATOMY

BASHOR, DAVID P
DEPT OF BIOLOGY
UNIV N CAROLINA AT
CHARLOTTE
CHARLOTTE, NC 28223
(704) 597-4047

BAUR, JOHN M
DEPT OF BIOLOGY
BRESCIA COLLEGE
120 WEST SEVENTH ST
OWENSBORO, KY 42301
(502) 685-3131 EXT 276

BELLMER, SISTER ELIZABETH H
TRINITY COLLEGE
WASHINGTON, DC 20017
(202) 939-5190

BENNETT, THOMAS E
DEPT OF BIOLOGY
BELLARMINE COLLEGE
NEWBURG ROAD
LOUISVILLE, KY 40205
(502) 452-8198

BERGQUIST, BART
DEPT OF BIOLOGY
UNIV NORTHERN IOWA
CEDAR FALLS, IA 50614
(319) 273-2723

BUSHBY, PHILIP A
COLLEGE OF VET MED
DRAWER V
MISS STATE UNIV, MS 39762
(601) 325-1127

DICKINSON, WINIFRED
DEPT OF BIOLOGY
UNIV OF STEUBENVILLE
STEUBENVILLE, OH 43952
(614) 283-3771

DUGGAN, ELEANOR L
BIOLOGY DEPT
UNIV N CAROLINA AT
GREENSBORO
GREENSBORO, NC 27412-5001
(919) 379-5839

ELDER, DR BETTY
DEPT OF BIOLOGY
GEORGIA SOUTHWESTERN
COLLEGE
AMERICUS, GA 31709
(912) 928-1250

FERNER, JOHN W
DEPT OF BIOLOGY
THOMAS MORE COLLEGE
CRESTVIEW HILLS, KY 41017
(606) 344-3374

FINKELSTEIN, MICHAEL
DEPT OF ORAL PATHOLOGY
COLLEGE OF DENTISTRY
UNIV OF IOWA
IOWA CITY, IA 52242
(319) 353-7370

FREED, DR JAMES M
DEPT OF ZOOLOGY
OHIO WESLEYAN UNIV
DELAWARE, OH 43015
(614) 369-4431 EXT 400

GOOCH, VAN D
DEPT OF SCI & MATH
UNIV OF MINNESOTA
MORRIS, MN 56267
(612) 589-2211

GWINN, DR JOHN F
DEPT OF BIOLOGY
UNIV OF AKRON
AKRON, OH 44325
(216) 375-7160

GWYN, DR D G
DEPT OF ANATOMY
DALHOUSIE UNIV
HALIFAX, NOVA SCOTIA
B3H 4H7 CANADA
(902) 424-2051

HERRON, MARY A
BIOMED LEARNING RES CTR
COLLEGE OF VET MED
TEXAS A&M UNIV
COLLEGE STATION, TX 77843
(409) 845-1780

HILLIARD, STEPHEN
DEPT OF BIOLOGY
BALDWIN-WALLACE
COLLEGE
BEREA, OH 44017
(216) 826-2265

HOUSE, EDWIN W
DEPT OF BIOLOGY
IDAHO STATE UNIV
PO BOX 8007
POCATELLO, ID 83209
(208) 236-3765

HOUSE, DR HERBERT W
ELON COLLEGE
BOX 2270
ELON COLLEGE, NC 27244
(919) 584-2294

JONES, MICHAEL E
DEPTS OF ANAT & HIST
FLINDERS UNIV OF SOUTH
AUSTRALIA
SCHOOL OF MEDICINE
BEDFORD PARK, 5042
AUSTRALIA

KEETE, J RICHARD
DEPT OF ANATOMY
CASE WESTERN RESERVE
UNIVERSITY
CLEVELAND, OH 44106
(216) 368-2656

MESSICK, JOHN P
DEPT OF BIOLOGY
MISSOURI SOUTHERN STATE
COLLEGE
JOPLIN, MO 64801
(417) 625-9376

MEYERS, PAUL E
DEPT OF BIOL CHEM &
STRUCT
THE CHICAGO MED SCHOOL
3333 GREEN BAY RD
NORTH CHICAGO, IL 60064
(312) 578-3000 EXT 458

MICKUS, JOHN
DEPT OF BIOLOGY
ILLINOIS BENEDICTINE COLL
5700 COLLEGE ROAD
LISLE, IL 60532-0900
(312) 960-1500 EXT 509

RALSTON, H J
DEPT OF ANATOMY S-1334
UNIV CALIF, SAN FRANCISCO
3RD & PARNASSUS AVES
SAN FRANCISCO, CA 94143
(415) 476-1861

ROBBINS, DR HERBERT C
DALLAS BAPTIST UNIV
7777 WEST KIEST BLVD
DALLAS, TX 75211-9800
(214) 333-5302

SINNAMON, WALT
CENTRAL WESLEYAN
COLLEGE, BOX 443
CENTRAL, SC 29630
(803) 639-2453 EXT 356

SMALL, JAMES W
DEPT OF BIOLOGY
ROLLINS COLLEGE, BOX 2643
WINTER PARK, FL 32789
(305) 646-2433

0742-3233/88/$0.00 + 2.00

SPRAGUE, RUTH M
DEPTS OF ANATOMY &
NEUROBIOLOGY
UNIV OF VERMONT COLLEGE
OF MEDICINE
BURLINGTON, VT 05405
(802) 656-0416

WILHELM, DALLAS
DEPT OF BIOLOGY
HASTINGS COLLEGE
HASTINGS, NE 68901
(402) 463-2402 EXT 264

WILLIAMS, STANLEY C
DEPT OF BIOL SCIENCES
SAN FRANCISCO STATE UNIV
1600 HOLLOWAY AVE
SAN FRANCISCO, CA 94132

WILSON, DR MARLENE
UNIV OF PORTLAND
5000 N WILLAMETTE BLVD
PORTLAND, OR 97203
(503) 283-7123

ZEITTER, SHIRLEY
DAVENPORT COLLEGE
415 EAST FULTON
GRAND RAPIDS, MI 49503
(616) 451-3511

ANIMAL BEHAVIOR

AMLANER, CHARLES J JR
DEPT OF ZOOLOGY
UNIV OF ARKANSAS
FAYETTEVILLE, AR 72701

ASHTON, GEOFFREY C
DEPT OF GENETICS
UNIV OF HAWAII
1960 EAST-WEST ROAD
HONOLULU, HI 96822
(808) 948-8552

ROGER GAMBS,
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2551

HECKENLIVELY, DONALD B
DEPT OF BIOLOGY
HILLSDALE COLLEGE
HILLSDALE, MI 49242
(517) 437-7341

KESLER, DAVID H
DEPT OF BIOLOGY
RHODES COLLEGE
2000 NORTH PARKWAY
MEMPHIS, TN 38112
(901) 726-3557

LA BAR, MARTIN
CENTRAL WESLEYAN
COLLEGE
CENTRAL, SC 29630
(803) 639-2453

ODE, PHILIP
DEPT OF BIOLOGY
THIEL COLLEGE
GREENVILE, PA 16125
(412) 588-7700

STOUT, JOHN
DEPT OF BIOLOGY
ANDREWS UNIV
BERRIEN SPRINGS, MI 49104
(616) 471-3243

ANIMAL SCIENCE

KENNELLY, DR JOHN J
DEPT OF ANIMAL SCIENCE
UNIV OF ALBERTA
EDMONTON, ALBERTA
CANADA T6G 2P5
(403) 432-2133

BIOCHEMISTRY

BATES, WILLIAM K
DEPT OF BIOLOGY
UNIV NORTH CAROLINA
GREENSBORO, NC 27412
(919) 379-5391

BLANCHAER, MARCEL
DEPT OF BIOCHEMISTRY
FACULTY OF MEDICINE
UNIV OF MANITOBA
WINNIPEG, MANITOBA
CANADA R3E 0W3
(204) 788-6570

COOK, DAVID E
DIV SCI & MATHEMATICS
DAKOTA STATE COLLEGE
MADISON, SD 57042-1799
(605) 252-5194

CREUTZ, CHARLES
DEPT OF BIOLOGY
UNIV TOLEDO
TOLEDO, OH 43606
(419) 537-4159

DICKINSON, WINIFRED
DEPT OF BIOLOGY
UNIV OF STEUBENVILLE
STEUBENVILLE, OH 43952
(614) 283-3771

EUSTIS-TURF, ELIZABETH
MEDICAL COLLEGE OF
VIRGINA
BOX 694, MCV STATION
RICHMOND, VA 23298
(804) 786-9824

FERNER, JOHN W
DEPT OF BIOLOGY
THOMAS MORE COLLEGE
CRESTVIEW HILLS, KY 41017
(606) 344-3374

FORRESTER, JOE
DEPT OF BIOCHEMISTRY
UNIV OF MISSOURI
M121 MED SCI BLDG
COLUMBIA, MO 65212
(314) 882-8795

HARLEY, CALVIN B
DEPT OF BIOCHEMISTRY
McMASTER UNIV
HAMILTON, ONTARIO
CANADA L8N 3Z5
(416) 525-9140 EXT 2040

HOUSE, DR HERBERT W
ELON COLLEGE, BOX 2270
ELON COLLEGE, NC 27244
(919) 584-2294

JOHNSON, WALTER
NW COLLEGE OF CHIROPRACTIC
2501 W 84TH ST
BLOOMINGTON, MN 55431
(612) 888-4777 EXT 290

KIRBY, DR EDWARD
DEPT OF BIOCHEMISTRY
TEMPLE UNIV HLTH SCI CTR
3420 N BROAD ST
PHILADELPHIA, PA 19140
(215) 221-4180

KRUSE, ANNA C
CABRINI COLLEGE
RADNOR, PA 19087
(215) 687-2100

MASSEY, K LORNE
DEPT OF PATHOLOGY
COLLEGE OF MEDICINE
UNIV SASKATCHEWAN
SASKATOON,
SASKATCHEWAN
CANADA S7N 0W0

NORRIS, THOMAS E
SENIOR ASSOC DEAN
MOREHOUSE SCH OF MED
720 WESTVIEW DR SW
ATLANTA, GA 30310-1495

PEARSON, ANDREW
DEPT OF BIOCHEMISTRY
UNIV WEST INDIES
MONA, KINGSTON 7
JAMAICA
(809) 927-2290

PETERSON, JULIAN A
DEPT OF BIOCHEMISTRY
UNIV TEXAS HEALTH SCI CTR
5323 HARRY HINES BLVD
DALLAS, TX 75235-9038
(214) 688-2361

RAWITCH, ALLEN B
DEPT OF BIOCHEMISTRY
UNIV KANSAS MED CTR
RAINBOW BLVD AT 39TH
KANSAS CITY, KS 66103
(913) 588-6957

SCHADLER, DANIEL L
DEPT OF BOLOGY
OGLETHORPE UNIV
4484 PEACHTREE ROAD NE
ATLANTA, GA 30319-2797
(404) 261-1441 EXT 403

SOLL, DIETER
DEPT OF MOLECULAR
BIOPHYS AND BIOCHEM
YALE UNIV
260 WHITNEY AVE
NEW HAVEN, CT 06511
(203) 436-3611

SPENCER, TREVOR
DEPT OF BIOCHEMISTRY
QUEEN'S UNIVERSITY
KINGSTON ONTARIO
CANADA K7L 3N6
(613) 545-2997

STRATTON, LEWIS P
DEPT OF BIOLOGY
FURMAN UNIV
GREENVILLE, SC 29613
(803) 294-3249

SUELTER, CLARENCE H
DEPT OF BIOCHEMISTRY
MICHIGAN STATE UNIV
EAST LANSING, MI 48824
(517) 355-1708

TESKEY, SISTER NANCY
HOLY NAMES COLLEGE
3500 MOUNTAIN BLVD
OAKLAND, CA 94619
(415) 436-0111

TREBLE, DONALD H
DEPT OF BIOCHEMISTRY
ALBANY MEDICAL COLLEGE
ALBANY, NY 12208
(518) 445-5364

WAGNER, MARTIN J
DEPT OF BIOCHEMISTRY
BAYLOR COLLEGE OF
DENTISTRY
3302 GASTON AVE
DALLAS, TX 75246
(214) 828-8261

WINTER, CHARLES G
DEPT OF BIOCHEMISTRY
UNIV OF ARKANSAS
COLLEGE OF MEDICINE
4301 W MARKHAM ST
LITTLE ROCK, AR 72205-7199
(501) 661-5190

BIOLOGY

BASHOR, DAVID P
DEPT OF BIOLOGY
UNIV N CAROLINA AT
CHARLOTTE
CHARLOTTE, NC 28223
(704) 597-4047

BAUR, JOHN M
DEPT OF BIOLOGY
BRESCIA COLLEGE
120 WEST SEVENTH ST
OWENSBORO, KY 42301
(502) 685-3131 EXT 276

BERG, VIRGINIA
DEPT OF BIOLOGY
UNIV OF NORTHERN IOWA
CEDAR FALLS, IA 50614
(319) 273-2770

BOWKER, LESLIE S
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE
UNIVERSITY
SAN LUIS OBISPO, CA 93407
(805) 546-2788

BROADWAY, RUBY L
DEPT OF NATURAL SCIENCE
DILLARD UNIVERSITY
NEW ORLEANS, LA 70122
(504) 283-8822 EXT 246

CARICO, JAMES E
DEPT OF BIOLOGY
LYNCHBURG COLLEGE
LYNCHBURG, VA 24501
(804) 522-8366

0742-3233/88/$0.00 + 2.00

CHEW, FS
DEPT OF BIOLOGY
TUFTS UNIV
MEDFORD, MA 02155
(617) 381-3189 EXT 3195

CHIEN, PAUL K
DEPT OF BIOLOGY
UNIV OF SAN FRANCISCO
SAN FRANCISCO, CA 94117
(415) 666-6345

COCKERHAM, BILL
FRESNO PACIFIC COLLEGE
1717 S CHESTNUT
FRESNO, CA 93702
(209) 453-2045

COLLINS, DR MICHAEL A J
DEPT OF BIOLOGY
MEMORIAL UNIV OF NEWFOUNDLAND
ST JOHN'S, NEWFOUNDLAND
CANADA A1B 3X9
(709) 737-8031

DILLEHAY, DR JANE
DEPT OF BIOLOGY
GALLAUDET COLLEGE
800 FLORIDA AVE NE
WASHINGTON, DC 20002
(202) 651-5531

DOVE, LEWIS
DEPT OF BIOL SCIENCES
WESTERN ILLINOIS UNIV
MACOMB, IL 61455
(309) 298-1166

DUGGAN, ELEANOR L
BIOLOGY DEPT
UNIV OF N CAROLINA AT GREENSBORO
ROOM 309, EBERHART BLDG
GREENSBORO, NC 27412-5001
(919) 379-5839

EILEUS, LAWRENCE J
DEPT OF BIOLOGY
UNIV OF NORTHERN IOWA
CEDAR FALLS, IA 50614
(319) 273-2218

FANNING, MARSHA E
DEPT OF BIOLOGY
LENOIR-RHYNE COLLEGE
HICKORY, NC 28603
(704) 328-7270

FERNER, JOHN W
DEPT OF BIOLOGY
THOMAS MORE COLLEGE
CRESTVIEW HILLS, KY 41017
(606) 344-3374

FONTANE, DR AR
DEPT OF BIOLOGY
UNIV OF VICTORIA
PO BOX 1700
VICTORIA, BC V8W 2Y2
CANADA
(604) 721-7131

FREY, DENNIS
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIVERSITY
SAN LUIS OBISPO, CA 93407
(805) 546-2802

FROLA, JOHN L
DEPT OF BIOLOGY
UNIV OF AKRON
AKRON, OH 44325
(216) 375-7153

GIBSON, LINDA
DEPT OF BIOLOGY
EASTERN WASH UNIV
CHENEY, WA 99004
(509) 359-2845

GORMAN, MARK
BALDWIN-WALLACE COLL
BEREA, OH 44017
(216) 826-2217

HAMAN, AC
DEPT OF BIOLOGY
UNIV NORTHERN IOWA
CEDAR FALLS, IA 50614
(319) 273-2726

HECKENLIVELY, DONALD B
DEPT OF BIOLOGY
HILLSDALE COLLEGE
HILLSDALE, MI 49242
(517) 437-7341

HEDMAN, STEPHEN C
DEPT OF BIOLOGY
UNIV OF MINN AT DULUTH
2400 OAKLAND AVE
DULUTH, MN 55812
(218) 726-8122

HEIMBROOK, MARGARET E
DEPT OF BIOL SCIENCES
UNIV OF NORTHERN COLORADO
GREELEY, CO 80639
(303) 351-2644

HODGSON, DR LYNN M
NORTHERN STATE COLLEGE
BOX 673
ABERDEEN, SD 57401
(605) 222-2432

HOUSE, EDWIN W
DEPT OF BIOLOGY
IDAHO STATE UNIV
PO BOX 8007
POCATELLO, ID 83209
(208) 236-3765

HOUSE, DR HERBERT W
ELON COLLEGE
BOX 2270
ELON COLLEGE, NC 27244
(919) 584-2294

HUMORA, PAUL
DEPT OF BIOLOGY
NORTH ADAMS ST COLLEGE
NORTH ADAMS, MA 01267
(413) 664-4511 EXT 343

JANKAY, PETER
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIVERSITY
SAN LUIS OBISPO, CA 93407
(805) 546-2860

JOHNSON, J RONALD
DEPT OF BIOLOGY
MIDLAND COLLEGE
FREMONT, NE 68025

KESSLER, SISTER IRMA
DEPT OF BIOLOGY
COLLEGE OF ST ELIZABETH
CONVENT STATION, NJ 07961
(201) 539-1600

KLEINSMITH, LEWIS J
DEPT OF BIOLOGY
UNIV OF MICHIGAN
ANN ARBOR, MI 48109-1048
(313) 763-3290

KRUSE, ANNA C
CABRINI COLLEGE
RADNOR, PA 19087
(215) 687-2100

LEISMAN, DR GILBERT A
DEPT OF BIOLOGY
EMPORIA STATE UNIV
EMPORIA, KS 66801
(316) 343-1200 EXT 5617

McCALLEY, DAVID V
DEPT OF BIOLOGY
UNIV NORTHERN IOWA
CEDAR FALLS, IA 50614
(319) 273-2581

McGIVERN, MARY JEAN
DEPT OF BIOLOGY
GEORGIAN COURT COLLEGE
LAKEWOOD, NJ 08701
(201) 364-2200 EXT 345

MELE, FRANK M
DEPT OF BIOLOGY
JERSEY CITY STATE COLLEGE
JERSEY CITY, NJ 07305-1597
(201) 547-3054

ODE, PHILIP
DEPT OF BIOLOGY
THIEL COLLEGE
GREENVILE, PA 16125
(412) 588-7700

ORR, ALAN
DEPT OF BIOLOGY
UNIV NORTHERN IOWA
CEDAR FALLS, IA 50614
(319) 273-2150

OWEN, LAWTON
KANSAS WESLEYAN
100 E CLAFLIN
SALINA, KS 67401
(913) 827-5541

PIPERBERG, JOEL B
DEPT OF BIOLOGY
SIMMONS COLLEGE
300 THE FENWAY
BOSTON, MA 02115
(617) 738-2196

POLLOCK, LW
DEPT OF BIOLOGY
DREW UNIVERSITY
MADISON, NJ 07940
(201) 377-3000 EXT 358

QUINN, DAVID L
DEPT OF BIOLOGY
MUSKINGUM COLLEGE
NEW CONCORD, OH 43762
(614) 826-8225

RALPH, CHARLES L
DEPT OF ZOOLOGY
COLORADO STATE UNIV
FT COLLINS, CO 80523
(303) 491-6105

RALSTON, HJ
DEPT OF ANATOMY S-1334
UNIV CALIFORNIA AT SAN FRANCISCO
SAN FRANCISCO, CA 94143
(415) 476-1861

RENISH, ALMA JEAN
UNIV OF WISCONSIN – PARKSIDE
BOX 2000
KENOSHA, WI 53141-2000
(414) 553-2213

ROBBINS, DR HERBERT C
DALLAS BAPTIST UNIV
7777 WEST KIEST BLVD
DALLAS, TX 75211-9800
(214) 333-5302

RUNYAN, MICHAEL E
DEPT OF BIOLOGY
LANDER COLLEGE
GREENWOOD, SC 29646
(803) 229-8385

SAVAGE, WAYNE
DEPT OF BIOLOGY
SAN JOSE STATE UNIV
SAN JOSE, CA 95192
(408) 277-2355

SCHADLER, DANIEL L
DEPT OF BIOLOGY
OGLETHORPE UNIV
4484 PEACHTREE ROAD NE
ATLANTA, GA 30319-2797
(404) 261-1441 EXT 403

SCHNEIWEISS, JEANNETTE W
DEPT OF BIOLOGY
HOFSTRA UNIV
HEMPSTEAD, NY 11550
(516) 560-5521

SCHWARTZ, ORLANDO A
DEPT OF BIOLOGY
UNIV NORTHERN IOWA
CEDAR FALLS, IA 50614
(319) 273-2106

SHOLES, OWEN DV
DEPT OF NATURAL SCIENCES
ASSUMPTION COLLEGE
500 SALISBURY ST
WORCESTER, MA 01609
(617) 752-5615 EXT 257

SINGLETARY, ROBERT L
DEPT OF BIOLOGY
UNIV OF BRIDGEPORT
BRIDGEPORT, CT 06601
(203) 576-4265

SINNAMON, WALT

0742-3233/88/$0.00 + 2.00

CENTRAL WESLEYAN
COLLEGE
BOX 443
CENTRAL, SC 29630
(803) 639-2453 EXT 356

SKAVARIL, DR RUSSELL V
DEPT OF GENETICS
OHIO STATE UNIV
961 BIOL SCI BLDG
484 WEST TWELFTH AVE
COLUMBUS, OH 43210
(614) 422-1310

SMALL, JAMES W
DEPT OF BIOLOGY
ROLLINS COLLEGE
BOX 2643
WINTER PARK, FL 32789
(305) 646-2433

SOBIESKI, ROD
DEPT OF BIOLOGY
EMPORIA STATE UNIV
EMPORIA, KS 66801
(316) 343-1200 EXT 5620

STANSFIELD, WILLIAM
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2875

STANTON, GEORGE E
DEPT OF BIOLOGY
COLUMBUS COLLEGE
COLUMBUS, GA 31993
(404) 568-2065

STEIN, PAUL
DEPT OF BIOLOGY
WASHINGTON UNIV
ST LOUIS, MO 63130
(314) 889-6824

STEUCEK, DR GUY L
DEPT OF BIOLOGY
MILLERSVILLE UNIV
MILLERSVILLE, PA 17551
(717) 872-3339

STONE, LARRIE E
DANA COLLEGE
BLAIR, NE 68008
(402) 426-4101 EXT 229

STRATTON, LEWIS P
DEPT OF BIOLOGY
FURMAN UNIV
GREENVILLE, SC 29613
(803) 294-3249

SWEET, HAVEN
DEPT OF BIOLOGY
UNIV OF CENTRAL FLORIDA
ORLANDO, FL 32816
(305) 275-2922

TAUB, STEPHAN R
DEPT OF BIOLOGY
GEORGE MASON UNIV
FAIRFAX, VA 22030
(703) 323-2181

TESKEY, SISTER NANCY
HOLY NAMES COLLEGE
OAKLAND, CA 94619
(415) 436-0111

TURNELL, MJ
DEPT OF ZOOLOGY
UNIVERSITY OF ALBERTA
EDMONTON, ALBERTA
CANADA T6G 2E9
(403) 432-0665

VERCH, RICHARD
DEPT OF BIOLOGY
NORTHLAND COLLEGE
ASHLAND, WI 54806
(715) 682-4531 EXT 335

VOORHEES, FRANK RAY
DEPT OF BIOLOGY
CENTRAL MISSOURI STATE
UNIV
WARRENSBURG, MO 64093
(816) 429-4933

WALLACE, ROBERT L
DEPT OF BIOLOGY
RIPON COLLEGE
RIPON, WI 54971
(414) 748-8122

WALTERS, DIRK R
DEPT OF BIOLOGY
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2721

WEISS, DR EDWARD
CHRISTOPHER NEWPORT
COLLEGE
50 SHOE LANE
NEWPORT NEWS, VA 23606
(804) 599-7044

WHALLS, MARVIN J
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-1357

WILHELM, DALLAS
DEPT OF BIOLOGY
HASTINGS COLLEGE
HASTINGS, NE 68901
(402) 463-2402 EXT 264

BIOMETRICS

BEAVER, JAMES S
DEPT OF AGRONOMY AND
SOILS
COLLEGE OF AGRICULTURAL
SCIENCE
UNIV OF PUERTO RICO
MAYAGUEZ, P R 00708
(809) 834-4040 EXT 2380

BOYNTON, DR JOHN E
ST JOSEPH'S COLLEGE
155 ROE BLVD
PATCHOGUE, NY 11772
(516) 654-3200

STEUCEK, DR GUY L
DEPT OF BIOLOGY
MILLERSVILLE UNIV
MILLERSVILLE, PA 17551
(717) 872-3339

WATROUS, JAMES
DEPT OF BIOLOGY
ST JOSEPH'S UNIV
PHILADELPHIA, PA 19131
(215) 879-7342

WESSEL-BEAVER, LINDA
DEPT OF AGRONOMY AND
SOILS
COLLEGE OF AGRICULTURAL
SCIENCE
UNIV OF PUERTO RICO
MAYAGUEZ, P R 00708
(809) 834-4040 EXT 2566

WILLIAMS, STANLEY C
DEPT OF BIOL SCIENCES
SAN FRANCISCO STATE UNIV
SAN FRANCISCO, CA 94132

BIOPHYSICS

AMLANER, CHARLES J, JR
DEPT OF ZOOLOGY
UNIV OF ARKANSAS
FAYETTEVILLE, AR 72701

RAM, JEFFREY L
DEPT OF PHYSIOLOGY
WAYNE STATE UNIV SCH
MEDICINE
DETROIT, MI 48201
(313) 577-1558

SACHS, DR FREDERICK
DEPT OF BIOPHYSICAL SCI
SUNY AT BUFFALO
BUFFALO, NY 14214
(716) 831-3289

SLAYMAN, C L
DEPT OF PHYSIOLOGY
YALE SCHOOL OF MEDICINE
NEW HAVEN, CT 06510-8026
(203) 788-4478

WUNDER, CHARLES C
DEPT OF PHYSIOLOGY
UNIV OF IOWA
OAKDALE CAMPUS
OAKDALE IA 52319
(319) 353-4704

BIOSTATISTICS

HECKENLIVELY, DONALD B
DEPT OF BIOLOGY
HILLSDALE COLLEGE
HILLSDALE, MI 49242
(517) 437-7341

PETERSON, MARGARET GE
BIOSTATISTICS RES CTR
UNIV OF CONNECTICUT
HEALTH CTR AM034
FARMINGTON, CT 06062
(203) 674-3834

SAKTI, JANA
DEPT OF CROP SCIENCE
UNIV OF SASKATCHEWAN
SASKATOON, SK S7N 0W0
CANADA
(306) 966-4952

BOTANY

BLACK, JOE B
DEPT OF BIOLOGY
LOUISIANA COLLEGE
PINEVILLE, LA 71359
(318) 487-7611

CASTANER, DAVID
DEPT OF BIOLOGY
CENTRAL MISSOURI STATE
UNIVERSITY
WARRENSBURG, MO 64093
(816) 429-4933

DICKINSON, WINIFRED
DEPT OF BIOLOGY
UNIV OF STEUBENVILLE
STEUBENVILLE, OH 43952
(614) 283-3771

DOYLE, JAMES
DEPT OF BIOLOGY
AQUINAS COLLEGE
GRAND RAPIDS, MI 49506
(616) 459-8281 EXT 387

GIBSON, LINDA
DEPT OF BIOLOGY
EASTERN WASHINGTON UNIV
CHENEY, WA 99004
(509) 359-2845

HODGSON, DR LYNN M
NORTHERN STATE COLLEGE
ABERDEEN, SD 57401
(605) 222-2432

HOLLAND, V L
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2789

HOLM, F A
DEPT OF CROP SCI & PLANT
ECOLOGY
UNIV OF SASKATCHEWAN
SASKATOON, SK S7N 0W0
CANADA
(306) 966-5006

JANKAY, PETER
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2860

KEIL, DAVID J
DEPT OF BIOL SCIENCES
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2043

LA BAR, MARTIN
CENTRAL WESLEYAN COLL
CENTRAL, SC 29630
(803) 639-2453

ROBBINS, DR HERBERT C
DALLAS BAPTIST UNIV
DALLAS, TX 75211-9800
(214) 333-5302

RUNYAN, MICHAEL E
DEPT OF BIOLOGY
LANDER COLLEGE
GREENWOOD, SC 29646
(803) 229-8385

SAVAGE, WAYNE
DEPT OF BIOLOGY
SAN JOSE STATE UNIV
SAN JOSE, CA 95192
(408) 277-2355

SCHADLER, DANIEL L
DEPT OF BIOLOGY
OGLETHORPE UNIV
4484 PEACHTREE ROAD NE

0742-3233/88/$0.00 + 2.00

ATLANTA, GA 30319-2797
(404) 261-1441 EXT 403

SHAFI, M I
DEPT OF SCIENCE & MATH
RUST COLLEGE
HOLLY SPRINGS, MS 38635
(601) 252-4661

SNOW, MICHAEL D
DEPT OF PHYS & LIFE SCI
UNIVERSITY OF PORTLAND
500 N WILLAMETTE BLVD
PORTLAND, OR 97203
(503) 283-7175

TORRES, ANDREW M
DEPT OF BOTANY
UNIV OF KANSAS
LAWRENCE, KS 66044
(913) 864-4257

VERCH, RICHARD
DEPT OF BIOLOGY
NORTHLAND COLLEGE
ASHLAND, WI 54806
(715) 682-4531 EXT 335

WULFF, BARRY
DEPT OF BIOLOGY
EASTERN CONNSTATE UNIV
WILLIMANTIC, CT 06226
(203) 456-2231

YOSHIMURA, MICHAEL A
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2466

CELL BIOLOGY

BATES, WILLIAM K
DEPT OF BIOLOGY
UNIV OF NORTH CAROLINA
GREENSBORO, NC 27412
(919) 379-5391

BERNSTEIN, MAURICE H
DEPT OF ANAT & CELL BIOL
WAYNE STATE UNIV SCH
MEDICINE
540 E CANFIELD
DETROIT, MI 48201
(313) 577-1029

CREUTZ, CHARLES
DEPT OF BIOLOGY
UNIV OF TOLEDO
TOLEDO, OH 43606
(419) 537-4159

GRAY, F HARRIET
HOLLINS COLLEGE
BOX 9616
HOLLINS COLLEGE, VA 24020
(703) 362-6543

PRESCOTT, LANSING M
DEPT OF BIOLOGY
AUGUSTANA COLLEGE
SIOUX FALLS, SD 57197
(605) 336-4719

HEIDCAMP, WILLIAM
BIOLOGY DEPARTMENT
GUSTAVUS ADOLPHUS COLL
ST PETER, MN 56082
(507) 931-7325

RALSTON, H J
DEPT OF ANATOMY S-1334
UNIV OF CALIFORNIA, SAN
FRANCISCO
3RD & PARNASSUS AVES
SAN FRANCISCO, CA 94143
(415) 476-1861

SAVAGE, WAYNE
DEPT OF BIOLOGY
SAN JOSE STATE UNIV
SAN JOSE, CA 95192
(408) 277-2355

STENROOS, ORRIES O
BIOLOGY DEPARTMENT
LYNCHBURG COLLEGE
1501 LAKESIDE DRIVE
LYNCHBURG, VA 24501
(804) 522-8362

STONE, LARRIE E
DANA COLLEGE
BLAIR, NE 68008
(402) 426-4101 EXT 229

WILLIAMS, W E
DEPT OF BIOLOGY
TRINITY COLLEGE
HARTFORD, CT 06106
(203) 527-3151 EXT 570

CHEMISTRY

HESTON, W M
CTR FOR NATURAL SCIENCES
NEW YORK INST TECH
OLD WESTBURY, NY 11568
(516) 686-7665

COMPUTERS/COMP LITERACY

CHARDINE, DR JOHN W
DEPT OF BIOL SCIENCES
BROCK UNIVERSITY
ST CATHARINES, ONTARIO
CANADA L2S 3A1
(416) 688-5550

CODY, RONALD
DEPT OF ENVIRON &
COMMUNITY MED
RUTGERS MED SCHOOL
PISCATAWAY, NJ 08854
(201) 463-4490

CORBEIL, ROBERT R
DEPTS OF MATHEMATICS &
COMPUT SCI
UNIV OF SAN DIEGO
SAN DIEGO, CA 92110
(619) 260-4600 EXT 4459

DUGGAN, ELEANOR L
BIOLOGY DEPT
UNIV OF N CAROLINA AT
GREENSBORO
ROOM 309, EBERHART BLDG
GREENSBORO, NC 27412-5001
(919) 379-5839

DURY, CARL G
OFFICE OF COMP & INFO
SERVICES
TEMPLE UNIV HLTH SCI CTR
3333 NO BROAD ST, RM 327
PHILADELPHIA, PA 19140
(215) 221-3479

HOFMANN, WALLACE C
DEPT OF PLANT SCIENCE
UNIV OF ARIZONA
BUILDING #36
TUCSON, AZ 85721
(602) 621-1257

KREIDER, DR DAVID L
DEPT OF ANIMAL SCIENCES
UNIV OF ARKANSAS
FAYETTEVILLE, AR 72701
(501) 575-4870

KRULL, DR SARA
SCHOOL OF NURSING
ST LOUIS UNIV MED CTR
ST LOUIS, MO 63104
(314) 577-8903

LEONG, KINGSTON
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2788

LIBEY, TERRY
DEPT OF HEALTH CAREERS
LANSING COMMUNITY
COLLEGE
419 N CAPITOL AVE
LANSING, MI 48901-7211

OLTJEN, JW
DEPT OF ANIMAL SCIENCE
OKLAHOMA STATE UNIV
STILLWATER, OK 74078
(405) 624-6670

OWEN, WILLIS L
3224 N ROFF
OKLAHOMA CITY, OK 73112
(405) 271-2229

PARISI, ANTHONY J
WRIGHT STATE UNIV SCHOOL
OF MEDICINE
DAYTON, OH 45401-0927
(513) 376-6711

POTTINGER, JAN
RM2050 MSC
UNIV OF WISCONSIN AT
MADISON
MADISON, WI 53706
(608) 263-1595

SCHAAD, DOUGLAS C
DIV RES IN MED EDUC
UNIV OF WASHINGTON SC-45
SEATTLE WA 98195
(206) 543-9320

SESSLER, AMY
CURRICULAR SOFTWARE
STUDIO
TUFTS UNIVERSITY
MEDFORD, MA 02155
(617) 628-5000 EXT 2009

SKAVARIL, DR RUSSELL V
DEPT OF GENETICS
OHIO STATE UNIV
COLUMBUS, OH 43210
(614) 422-1310

STRINGFELLOW, HART R
DEPT OF DENTAL EDUCATION
UNIV OF FLORIDA COLLEGE
OF DENTISTRY
BOX J-406 JHMHC
GAINESVILLE, FL 32610
(904) 392-2674

WETSTONE, SCOTT
UNIV OF CONNECTICUT
HEALTH CTR AM033
FARMINGTON, CT 06032
(203) 674-3836

ZAJICEK, GERSHOM
MEDICAL COMPUTER
HEBREW UNIVERSITY-
HADASSAH MEDICAL
SCHOOL
P.O. BOX 1172
JERUSALEM, ISRAEL 91010
BITNET GERSHOM@HUJIMD

CYTOGENETICS

GRANT, WILLIAM F
GENETICS LABORATORY
PO BOX 4000
MACDONALD CAMPUS OF
McGILL UNIV
STE ANNE DE BELLEVUE
QUEBEC, CANADA H9X 1C0

CYTOLOGY

GRANT, WILLIAM F
GENETICS LABORATORY
PO BOX 4000
MACDONALD CAMPUS OF
McGILL UNIV
STE ANNE DE BELLEVUE
QUEBEC, CANADA H9X 1C0

KEETE, J RICHARD
DEPT OF ANATOMY
CASE WESTERN RESERVE
UNIV
CLEVELAND, OH 44106
(216) 368-2656

DENTISTRY

TOWNSEND, DeWAYNE
SCHOOL OF DENTISTRY
16-262 MOOS TOWER
UNIVERSITY OF MINNESOTA
MINNEAPOLIS, MN 55455
(612) 625-7467

DEVELOPMENTAL BIOLOGY

HEIDCAMP, WILLIAM
BIOLOGY DEPARTMENT
GUSTAVUS ADOLPHUS COLL
ST PETER, MN 56082
(507) 931-7325

RALSTON, HJ
DEPT OF ANATOMY S-1334
UNIV CALIFORNIA AT SAN
FRANCISCO
3RD & PARNASSUS AVES
SAN FRANCISCO, CA 94143
(415) 476-1861

STONE, LARRIE E
DANA COLLEGE
BLAIR, NE 68008
(402) 426-4101 EXT 229

VOORHEES, FR
DEPT OF BIOLOGY
CENTRAL MISSOURI STATE
UNIV
WARRENSBURG, MO 64093
(816) 429-4933

0742-3233/88/$0.00 + 2.00

AIMS AND SCOPE

The goal of *Computers in Life Science Education* is to provide a means of communication among life science educators who anticipate or are currently employing the computer as an educational tool. The range of content includes, but is not limited to, articles focusing on computer applications and their underlying philosophy, reports on faculty/student experiences with computers in teaching environments, and software/hardware reviews in both basic science and clinical education settings.

INVITATION TO CONTRIBUTORS

Articles consistent with the goals of *Computers in Life Science Education* are invited for possible publication in the newsletter.

PREPARATION AND SUBMISSION OF MATERIAL

Articles submitted for publication should not exceed 2000 words and should be typewritten, double spaced, with wide margins. The original and two copies including two sets of figures and tables should be sent to the Editor: Dr. Harold Modell, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

Title page should include full title, list of authors, academic or professional affiliations, and complete address and phone number of the corresponding author.

Illustrations should be submitted as original drawings in India ink or sharp, unmounted photographs on glossy paper. The lettering should be such that it can be legible after reduction (width of one column = 5.7 cm).

Reference style and form should follow the "number system with references alphabetized" described in the Council of Biology Editors Style Manual. References should be listed in alphabetical order by the first author's last name, numbered consecutively, and cited in the text by these numbers.

RESPONSIBILITY AND COPYRIGHT

Authors are responsible for accuracy of statements and opinions expressed in articles. All authors submitting manuscripts will be sent a copyright transfer form to complete. The completed form must be returned before the work will be published.

SUBSCRIPTION INFORMATION

Computers in Life Science Education is published monthly by National Resource for Computers in Life Science Education, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Subscription rate is $30.00 for 12 issues, including postage and handling in the United States and Canada. Add $20.00 for postage (airmail) in Mexico and Europe and $23.00 for the rest of the world.

This newsletter has been registered with the Copyright Clearance Center, Inc. Consent is given for copying of articles for personal or internal use, or for the personal or internal use of specific clients. This consent is given on the condition that the copier pay through the Center the per-copy fee stated in the code on the first page for copying beyond that permitted by the US Copyright Law. If no code appears on an article, the author has not given broad consent to copy and permission to copy must be obtained directly from the author. This consent does not extend to other kinds of copying, such as for general distribution, resale, advertising and promotional purposes, or for creating new collective works.

Address orders, changes of address, and claims for missing issues to NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Claims for missing issues can be honored only up to three months for domestic addresses and six months for foreign addresses. Duplicate copies will not be sent to replace ones undelivered due to failure to notify NRCLSE of change of address.

Address editorial correspondence to Harold I. Modell, PhD, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. (BITNET MODELL@UWALOCKE)

POSTMASTER: Send address changes to *Computers in Life Science Education*, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

0742-3233/88/$0.00 + 2.00

VOLUME 5 NUMBER 3, MARCH 1988 CLSEE3 5(3)17-24, 1988 ISSN 0742-3233

COMPUTERS
IN LIFE
SCIENCE
EDUCATION

HAROLD I. MODELL
Department of Radiology
University of Washington
Seattle, Washington

MARCEL BLANCHAER
Department of Biochemistry
Faculty of Medicine
University of Manitoba
Winnipeg, Manitoba

THEODORE J. CROVELLO
Graduate Studies and Research
California State University, Los Angeles
Los Angeles, California

JAMES W. ECKBLAD
Department of Biology
Luther College
Decorah, Iowa

TSEGAYE HABTEMARIAM
School of Veterinary Medicine
Tuskegee University
Tuskegee, Alabama

DONNA LARSON
School of Nursing
Grand Valley State College
Allendale, Michigan

TERRY M. MIKITEN
Graduate School of Biomedical Sciences
University of Texas Health Science Center
San Antonio, Texas

JAMES E. RANDALL
Department of Physiology
Indiana University
Bloomington, Indiana

PATRICIA SCHWIRIAN
College of Nursing
Ohio State University
Columbus, Ohio

RICHARD STULL
College of Pharmacy
University of Arkansas
Little Rock, Arkansas

JAMES W. WOODS
Lister Hill National Center
for Biomedical Communications
National Library of Medicine
Bethesda, Maryland

DOROTHY WOOLEY-McKAY
Department of Biology
Glendale Community College
Glendale, Arizona

GLEN YOSHIDA
Department of Life Sciences
Los Angeles Southwest College
Los Angeles, California

NRCLSE

CONTENTS

CLSE 1987-88 COLLEAGUE DIRECTORY – PART II 17

KEEPING ABREAST OF THE LITERATURE 23

CLSE 1987-88 COLLEAGUE DIRECTORY – PART II

The primary goal of the National Resource for Computers in Life Science Education (NRCLSE) is to cultivate collaborative efforts among life science faculty interested in using the computer as a teaching tool.

The listing that follows is a continuation of the 1987-88 directory published last month. It is updated from the 1986-87 directory and was drawn primarily from respondents to questionnaires printed in CLSE. It is intended to help readers identify colleagues with common interest areas.

The listings are arranged by the content areas identified in response to the question, "What content areas do you teach?" As a result, entries may appear under more than one heading.

Although every attempt has been made to ensure that the information is current and correct, it is likely that some errors appear in this list. We apologize in advance for any inconveniences that may arise due to such oversights. The directory will be completed in next month's issue.

If you are aware of other colleagues that should be listed, please send the pertinent information (name, address, phone number, BITNET address, teaching content area) to NRCLSE, Mail Stop RC-70, Univ. of Washington, Seattle, WA 98195 or let us know via BITNET. NRCLSE's BITNET address is MODELL@UWALOCKE.

ECOLOGY
BEAVER, JAMES S
DEPT OF AGRONOMY AND SOILS
COLLEGE OF AGRIC SCI
UNIV OF PUERTO RICO
MAYAGUEZ, P R 00708
(809) 834-4040 EXT 2380

BELLMER, SISTER ELIZABETH H
TRINITY COLLEGE
WASHINGTON, DC 20017
(202) 939-5190

BOWKER, LESLIE S
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2788

BOYNTON, DR JOHN E
ST JOSEPH'S COLLEGE

0742-3233/88/$0.00 + 2.00

155 ROE BLVD
PATCHOGUE, NY 11772
(516) 654-3200

CACCAMISE, DONALD F
DEPT OF ENTOMOLOGY
RUTGERS UNIV
NEW BRUNSWICK, NJ 08903
(201) 932-9459

CALDWELL, DOUG
DEPT OF APPLIED MICRO &
FOOD SCI
UNIV OF SASKATCHEWAN
SASKATOON, SK S7N 0W0
CANADA
(306) 966-5026

CAMERON, DAVID G
DEPT OF BIOLOGY
MONTANA STATE UNIV
BOZEMAN, MT 59717
(406) 994-2670

CHARDINE, DR JOHN W
DEPT OF BIOL SCIENCES
BROCK UNIVERSITY
ST CATHARINES, ONTARIO
CANADA L2S 3A1
(416) 688-5550

CHEW, FS
DEPT OF BIOLOGY
TUFTS UNIV
MEDFORD, MA 02155
(617) 381-3189 EXT 3195

CLOUTIER,CONRAD
DEPT OF BIOLOGY
UNIVERSITY LAVAL
QUEBEC 10, QUEBEC
CANADA G1K 7P4
(418) 656-3183

COCKERHAM, BILL
FRESNO PACIFIC COLLEGE
FRESNO, CA 93702
(209) 453-2045

CYR, ANDRE
DEPT OF BIOLOGY
UNIV OF SHERBROOKE
SHERBROOKE, QUEBEC
CANADA J1K 2R1
(819) 821-7074

DOYLE, JAMES
DEPT OF BIOLOGY
AQUINAS COLLEGE
GRAND RAPIDS, MI 49506
(616) 459-8281 EXT 387

DUDLEY, PATRICIA L
DEPT OF BIOL SCIENCES
BARNARD COLLEGE
COLUMBIA UNIV
3009 BROADWAY
NEW YORK, NY 10027
(212) 280-2437

FANNING, MARSHA E
DEPT OF BIOLOGY
LENOIR-RHYNE COLLEGE
HICKORY, NC 28603
(704) 328-7270

GAMBS, ROGER
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2551

GILES, ROBERT H Jr
DEPT OF FISHERIES &
WILDLIFE SCIENCE
VIRGINIA POLYTECH INST &
STATE UNIV
BLACKSBURG, VA 24061
(703) 961-5910

HILTON, DONALD FJ
DEPT OF BIOL SCIENCE
BISHOP'S UNIV
LENNOXVILLE, QUEBEC
CANADA J1M 127
(819) 569-9551

HOLLAND, V L
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2789

JOHNSON, DAVID W
DEPT OF BIOLOGY
CONCORDIA COLLEGE
MOORHEAD, MN 56560
(218) 299-3085

JOHNSON, IVAN M
DEPT OF BIOLOGY
CONCORDIA COLLEGE
MOORHEAD, MN 56560
(218) 299-3085

KESLER, DAVID H
DEPT OF BIOLOGY
RHODES COLLEGE
MEMPHIS, TN 38112
(901) 726-3557

NOVEMSKY, LISA
NEW JERSEY INST TECH
NEWARK, NJ 07102
(201) 596-3253

ROBBINS, DR HERBERT C
DALLAS BAPTIST UNIV
DALLAS, TX 75211-9800
(214) 333-5302

SCHADLER, DANIEL L
DEPT OF BIOLOGY
OGLETHORPE UNIV
4484 PEACHTREE ROAD NE
ATLANTA, GA 30319-2797

SCHWARTZ, ORLANDO A
DEPT OF BIOLOGY
UNIV OF NORTHERN IOWA
CEDAR FALLS, IA 50614
(319) 273-2106

SHAFI, M I
DEPT OF SCIENCE & MATH
RUST COLLEGE
HOLLY SPRINGS, MS 38635
(601) 252-4661

SINGLETARY, ROBERT L
DEPT OF BIOLOGY
UNIV OF BRIDGEPORT
BRIDGEPORT, CT 06601
(203) 576-4265

SLOEY, WILLIAM E
DEPT OF BIOL/MICROBIOL
UNIV OF WISC AT OSHKOSH
OSHKOSH, WI 54901
(414) 424-3068

SNOW, MICHAEL D
DEPT OF PHYS & LIFE SCI
UNIVERSITY OF PORTLAND
500 N WILLAMETTE BLVD
PORTLAND, OR 97203
(503) 283-7175

STANTON, GEORGE E
DEPT OF BIOLOGY
COLUMBUS COLLEGE
COLUMBUS, GA 31993
(404) 568-2065

UNGAR, IRWIN A
DEPT OF BOTANY
OHIO UNIV
ATHENS, OH 45701

VAN AMBURG, GERALD L
DEPT OF BIOLOGY
CONCORDIA COLLEGE
MOORHEAD, MN 56560
(218) 299-3085

WALTERS, DIRK R
DEPT OF BIOLOGY
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2721

WEISS, DR EDWARD
CHRISTOPHER NEWPORT
COLLEGE
50 SHOE LANE
NEWPORT NEWS, VA 23606
(804) 599-7044

WERNER, J KIRWIN
DEPT OF BIOLOGY
NORTHERN MICHIGAN UNIV
MARQUETTE, MI 49855
(906) 227-2310

WOLF, THOMAS M
DEPT OF BIOLOGY
WASHBURN UNIV OF TOPEKA
TOPEKA, KS 66621
(913) 295-6768

WULFF, BARRY
DEPT OF BIOLOGY
EASTERN CONN STATE UNIV
WILLIMANTIC, CT 06226
(203) 456-2231

EDUCATION

GROBMAN, HULDA
ST LOUIS UNIV SCH MED
ST LOUIS, MO 63104
(314) 577-8645

KERBESHIAN, LYNN
UNIV OF NO DAK SCH MED
OMEE MED SCIENCE NO
GRAND FORKS, ND 58201
(701) 777-3833

KROGULL, STEVEN
DEPT OF EDUC SERVICES
MEDICAL COLLEGE OF WISC
MILWAUKEE, WI 53226
(414) 257-8546

McCRADY, WILLIAM
SCIENCE LEARNING CTR
UNIV OF TEXAS AT
ARLINGTON
BOX 19389
ARLINGTON, TX 76019
(817) 273-2129

ELECTRON MICROSCOPY

SAVAGE, WAYNE
DEPT OF BIOLOGY
SAN JOSE STATE UNIV
SAN JOSE CA 95192
(408) 277-2355

EMBRYOLOGY

BELLMER, SISTER ELIZABETH H
TRINITY COLLEGE
WASHINGTON, DC 20017
(202) 939-5190

BERNSTEIN, MAURICE H
DEPT OF ANAT & CELL BIOL
WAYNE STATE UNIV SCH
MEDICINE
540 E CANFIELD
DETROIT, MI 48201
(313) 577-1029

FEEBACK, DANIEL
DEPT OF ANATOMICAL SCI
UNIV OF OKLA HLTH SCI CTR
PO BOX 26901 BMSB540
OKLAHOMA CITY, OK 73190
(405) 271-2377

HARRIS, THOMAS M
DEPT OF ANATOMY
MED COLLEGE OF VIRGINIA
RICHMOND, VA 23298-0001
(804) 789-9534

HILLIARD, STEPHEN
DEPT OF BIOLOGY
BALDWIN-WALLACE COLL
BEREA, OH 44017
(216) 826-2265

KESSLER, SISTER IRMA
DEPT OF BIOLOGY
COLLEGE OF ST ELIZABETH
CONVENT STATION, NJ 07961
(201) 539-1600

MEYERS, PAUL E
DEPT OF BIOL CHEM &
STRUCT
THE CHICAGO MED SCHOOL
3333 GREEN BAY RD
NORTH CHICAGO, IL 60064
(312) 578-3000 EXT 458

ROBBINS, DR HERBERT C
DALLAS BAPTIST UNIV
DALLAS, TX 75211-9800
(214) 333-5302

ENDOCRINOLOGY

CHAVEZ, R SCOTT
P A PROGRAM
UNIV OF NEBRASKA MED CTR
OMAHA, NE 68105
(402) 559-5266

JEGLA, THOMAS C
DEPT OF BIOLOGY
KENYON COLLEGE
GAMBIER, OH 43022
(614) 427-2244

GRAY, F HARRIET
HOLLINS COLLEGE
HOLLINS COLLEGE, VA 24020
(703) 362-6543

RAWITCH, ALLEN B
DEPT OF BIOCHEMISTRY
UNIV KANSAS MED CTR
KANSAS CITY, KS 66103
(913) 588-6957

0742-3233/88/$0.00 + 2.00

SAGE, MARTIN
DEPT OF BIOLOGY
UNIV OF MISSOURI AT ST LOUIS
ST LOUIS, MO 63121
(314) 553-6218

SCHMIDT, THOMAS J
DEPT OF PHYSIOL & BIOPHYS
UNIV OF IOWA
5-432 BOWEN SCIENCE BLDG
IOWA CITY, IA 52242
(319) 353-4018

WOLF, RICHARD C
DEPT OF PHYSIOLOGY
UNIV OF WISCONSIN
MADISON, WI 53706
(608) 262-2939

ZIMMERMAN, JAY
DEPT OF BIOL SCIENCES
ST JOHN'S UNIV
GRAND CENTRAL & UTOPIA PKWS
NEW YORK, NY 11439
(718) 990-6161 EXT 5233

ENTOMOLOGY

CLOUTIER, CONRAD
DEPT OF BIOLOGY
UNIVERSITY LAVAL
QUEBEC 10, QUEBEC
CANADA G1K 7P4
(418) 656-3183

FARRIER, M H
DEPT OF ENTOMOLOGY
N. CAROLINA STATE UNIV
RALEIGH, NC 27695-7613
(919) 737-2833

HAMAN, A C
DEPT OF BIOLOGY
UNIV OF NORTHERN IOWA
CEDAR FALLS, IA 50614
(319) 273-2726

HILTON, DONALD FJ
DEPT OF BIOL SCIENCES
BISHOP'S UNIVERSITY
LENNOXVILLE, QUEBEC
CANADA J1M 1Z7
(819) 569-9551

JOHNSON, DONN T
DEPT OF ENTOMOLOGY
UNIV OF ARKANSAS
FAYETTEVILLE, AR 72701
(501) 575-2451

LAMP, WILLIAM
DEPT OF ENTOMOLOGY
UNIV OF MARYLAND
COLLEGE PARK, MD 20742
(301) 454-5875

LEONG, KINGSTON
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2788

MUSICK, G J
DEPT OF ENTOMOLOGY
UNIV OF ARKANSAS
FAYETTEVILLE, AR 72701
(501) 575-2451

ODE, PHILIP
DEPT OF BIOLOGY
THIEL COLLEGE
GREENVILE, PA 16125
(412) 588-7700

PICKERING, JOHN
DEPT OF ENTOMOLOGY
UNIV OF GEORGIA
ATHENS, GA
(404) 542-2816

WILLIAMS, STANLEY C
DEPT OF BIOL SCIENCES
SAN FRANCISCO STATE UNIV
SAN FRANCISCO, CA 94132

ENVIRONMENTAL SCIENCE

FORTNER, ROSANNE
OHIO STATE UNIV
SCHOOL OF NAT RESOURCES
COLUMBUS, OH 43210
(614) 422-2265

SABOSKI, ELEANOR M
NEW ENGLAND COLLEGE
HENNIKER, NH 03242
(603) 428-2374

SNOW, MICHAEL D
DEPT OF PHYS & LIFE SCI
UNIV OF PORTLAND
500 N WILLAMETTE BLVD
PORTLAND, OR 97203
(503) 283-7175

EPIDEMIOLOGY

KLAAS, JUDY C
DEPT OF BIOLOGY
FRAMINGHAM STATE COLL
FRAMINGHAM, MA 01701
(617) 620-1220 EXT 459

EVOLUTION

CARICO, JAMES E
DEPT OF BIOLOGY
LYNCHBURG COLLEGE
LYNCHBURG, VA 24501
(804) 522-8366

CHEW, FS
DEPT OF BIOLOGY
TUFTS UNIV
MEDFORD, MA 02155
(617) 381-3189 EXT 3195

FANNING, MARSHA E
DEPT OF BIOLOGY
LENOIR-RHYNE COLLEGE
HICKORY, NC 28603
(704) 328-7270

FERNER, JOHN W
DEPT OF BIOLOGY
THOMAS MORE COLLEGE
CRESTVIEW HILLS, KY 41017
(606) 344-3374

GORMAN, MARK
BALDWIN-WALLACE COLL
BEREA, OH 44017
(216) 826-2217

ODE, PHILIP
DEPT OF BIOLOGY
THIEL COLLEGE
GREENVILE, PA 16125
(412) 588-7700

SEAGER, BOB
DEPT OF BIOLOGY
UNIV OF NORTHERN IOWA
CEDAR FALLS, IA 50614
(319) 273-2670

STANSFIELD, WILLIAM
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2875

STANTON, GEORGE E
DEPT OF BIOLOGY
COLUMBUS COLLEGE
COLUMBUS, GA 31993
(404) 568-2065

WILLIAMS, W E
DEPT OF BIOLOGY
TRINITY COLLEGE
HARTFORD, CT 06106
(203) 527-3151 EXT 570

FAMILY PRACTICE

PARISI, ANTHONY J
WRIGHT STATE UNIV SCH MEDICINE
DAYTON, OH 45401-0927
(513) 376-6711

FISHERIES

WHALLS, MARVIN J
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-1357

GASTROENTEROLOGY

BARDE, CHRISTOPHER J
GI UNIT, VA MED CTR
4100 W THIRD ST
DAYTON, OH 45428
(513) 268-6511

GENETICS

ASHTON, GEOFFREY C
DEPT OF GENETICS
UNIV OF HAWAII
1960 EAST-WEST ROAD
HONOLULU, HI 96822
(808) 948-8552

BELLMER, SISTER ELIZABETH H
TRINITY COLLEGE
WASHINGTON, DC 20017
(202) 939-5190

BERNSTEIN, MAURICE H
DEPT OF ANAT & CELL BIOL
WAYNE STATE UNIV SCHOOL OF MEDICINE
DETROIT, MI 48201
(313) 577-1029

BLACK, JOE B
DEPT OF BIOLOGY
LOUISIANA COLLEGE
LOUISIANA COLLEGE STATION
PINEVILLE, LA 71359
(318) 487-7611

BOYNTON, DR JOHN E
ST JOSEPH'S COLLEGE
155 ROE BLVD
PATCHOGUE, NY 11772
(516) 654-3200

CAMERON, DAVID G
DEPT OF BIOLOGY
MONTANA STATE UNIV
BOZEMAN, MT 59717
(406) 994-2670

CARICO, JAMES E
DEPT OF BIOLOGY
LYNCHBURG COLLEGE
LYNCHBURG, VA 24501
(804) 522-8366

CORBEIL, ROBERT R
DEPT OF MATH & COMPUT SCI
UNIV OF SAN DIEGO
SAN DIEGO, CA 92110
(619) 260-4600 EXT 4459

DAVIS, THOMAS M
DEPT OF PLANT SCIENCE/GENETICS
UNIV OF NEW HAMPSHIRE
DURHAM, NH 03824-3597
(603) 862-3217

DICKINSON, WINIFRED
DEPT OF BIOLOGY
UNIV OF STEUBENVILLE
STEUBENVILLE, OH 43952
(614) 283-3771

DOYLE, JAMES
DEPT OF BIOLOGY
AQUINAS COLLEGE
GRAND RAPIDS, MI 49506
(616) 459-8281 EXT 387

FREED, DR JAMES M
DEPT OF ZOOLOGY
OHIO WESLEYAN UNIV
DELAWARE, OH 43015
(614) 369-4431 EXT 400

GORMAN, MARK
BALDWIN-WALLACE COLL
LIFE SCIENCE BLDG
BEREA, OH 44017
(216) 826-2217

GRANT, WILLIAM F
GENETICS LABORATORY
P.O. BOX 4000
MACDONALD CAMPUS
McGILL UNIV
STE ANNE DE BELLEVUE
QUEBEC H9X 1C0 CANADA

HEDMAN, STEPHEN C
DEPT OF BIOLOGY
221 LIFE SCI BLDG
UNIV OF MINNESOTA
2400 OAKLAND AVE
DULUTH, MN 55812
(218) 726-8122

JOHNSON, DAVID W
DEPT OF BIOLOGY
CONCORDIA COLLEGE
MOORHEAD, MN 56560
(218) 299-3085

JOHNSON, IVAN M
DEPT OF BIOLOGY
CONCORDIA COLLEGE
MOORHEAD, MN 56560
(218) 299-3085

KRAUSE, DR ELIOT
DEPT OF BIOLOGY
SETON HALL UNIV
SOUTH ORANGE, NJ 07079
(201) 761-9532

LA BAR, MARTIN
CENTRAL WESLEYAN COLLEGE
CENTRAL, SC 29630

(803) 639-2453

NICKLA, HARRY
DEPT OF BIOLOGY
CREIGHTON UNIV
OMAHA, NE 68178
(402) 280-2811

PIPERBERG, JOEL B
DEPT OF BIOLOGY
SIMMONS COLLEGE
300 THE FENWAY
BOSTON, MA 02115
(617) 738-2196

SEAGER, BOB
DEPT OF BIOLOGY
UNIV OF NORTHERN IOWA
CEDAR FALLS, IA 50614
(319) 273-2670

SHAFI, M I
DEPT OF SCIENCE & MATH
RUST COLLEGE
HOLLY SPRINGS, MS 38635
(601) 252-4661

SKAVARIL, DR RUSSELL V
DEPT OF GENETICS
OHIO STATE UNIV
COLUMBUS, OH 43210
(614) 422-1310

STANSFIELD, WILLIAM
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2875

STONE, LARRIE E
DANA COLLEGE
BLAIR, NE 68008
(402) 426-4101 EXT 229

TAUB, STEPHAN R
DEPT OF BIOLOGY
GEORGE MASON UNIV
FAIRFAX, VA 22030
(703) 323-2181

TORRES, ANDREW M
DEPT OF BOTANY
UNIV OF KANSAS
LAWRENCE, ES 66044
(913) 864-4257

VAN AMBURG, GERALD L
DEPT OF BIOLOGY
CONCORDIA COLLEGE
MOORHEAD, MN 56560
(218) 299-3085

VERCH, RICHARD
DEPT OF BIOLOGY
NORTHLAND COLLEGE
ASHLAND, WI 54806
(715) 682-4531 EXT 335

WALKER, RICHARD
STERLING COLLEGE
STERLING, KS 67579
(316) 278-2173

WILHELM, DALLAS
DEPT OF BIOLOGY
HASTINGS COLLEGE
HASTINGS, NE 68901
(402) 463-2402 EXT 264

WOLF, THOMAS M
DEPT OF BIOLOGY
WASHBURN UNIV OF TOPEKA
1700 COLLEGE AVE
TOPEKA, KS 66621
(913) 295-6768

HEMATOLOGY

GRADY, DAVID V
DEPT OF BIOL SCIENCES
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2883

KEETE, J RICHARD
DEPT OF ANATOMY
CASE WESTERN RESERVE U
CLEVELAND, OH 44106
(216) 368-2656

HISTOLOGY

ADAMS, DON
DEPT OF VETERINARY ANAT
IOWA STATE UNIV
AMES, IA 50011
(515) 294-7710

BENNETT, THOMAS E
DEPT OF BIOLOGY
BELLARMINE COLLEGE
NEWBURG ROAD
LOUISVILLE, KY 40205
(502) 452-8198

BERNSTEIN, MAURICE H
DEPT OF ANAT & CELL BIOL
WAYNE STATE UNIV SCHOOL
OF MEDICINE
DETROIT, MI 48201
(313) 577-1029

BLACK, JOE B
DEPT OF BIOLOGY
LOUISIANA COLLEGE
LOUISIANA COLLEGE
STATION
PINEVILLE, LA 71359
(318) 487-7611

HAKIM, RAZIEL S
DEPT OF ANATOMY
COLLEGE OF MEDICINE
HOWARD UNIV
WASHINGTON, DC 20059
(202) 636-6555

HARRIS, THOMAS M
DEPT OF ANATOMY
MEDICAL COLL OF VIRGINIA
BOX 709
RICHMOND, VA 23298-0001
(804) 789-9534

HERRON, MARY A
BIOMED LEARNING RES CTR
COLLEGE VET MED
TEXAS A&M UNIV
COLLEGE STATION, TX 77843
(409) 845-1780

JENSH, RONALD P
DEPT OF ANATOMY
JEFFERSON MEDICAL
COLLEGE
1200 LOCUST ST
PHILADELPHIA, PA 19107
(215) 928-6633

KEETE, J RICHARD
DEPT OF ANATOMY
CASE WESTERN RESERVE U
CLEVELAND, OH 44106
(216) 368-2656

KESSLER, SISTER IRMA
DEPT OF BIOLOGY
COLLEGE OF ST ELIZABETH
CONVENT STATION, NJ 07961
(201) 539-1600

MEYERS, PAUL E
DEPT OF BIOL CHEM &
STRUCT
THE CHICAGO MED SCH
3333 GREEN BAY RD NORTH
CHICAGO IL 60064
(312) 578-3000 EXT 458

MICKUS, JOHN
DEPT OF BIOLOGY
ILLINOIS BENEDICTINE COLL
LISLE, IL 60532-0900
(312) 960-1500 EXT 509

PADAWER, JACQUES
DEPT OF ANAT & STRUCT
BIOLOGY
ALBERT EINSTEIN COLLEGE
OF MEDICINE
BRONX, NY 10461
(212) 430-3057

PAULSEN, DOUGLAS F
DEPT OF ANATOMY
MOREHOUSE SCH OF MED
720 WESTVIEW DR SW
ATLANTA, GA 30310
(404) 752-1559

VOORHEES, FRANK RAY
DEPT OF BIOLOGY
CENTRAL MISSOURI STATE
UNIV, WCM 306
WARRENSBURG, MO 64093
(816) 429-4933

WILLISTON, JOHN S
DEPT OF BIOLOGY
SAN FRANCISCO STATE UNIV
1600 HOLLOWAY AVE
SAN FRANCISCO, CA 94132
(415) 584-5319

IMMUNOLOGY

ALBRITTON, WILLIAM L
DEPT OF MICROBIOLOGY
UNIV OF SASKATCHEWAN
SASKATOON, SK S7N 0W0
CANADA
(306) 966-4306

BAUR, JOHN M
DEPT OF BIOLOGY
BRESCIA COLLEGE
120 WEST SEVENTH ST
OWENSBORO, KY 42301
(502) 685-3131 EXT 276

CREUTZ, CHARLES
DEPT OF BIOLOGY
UNIV OF TOLEDO
2801 W BANCROFT ST
TOLEDO, OH 43606
(419) 537-4159

HALL, LEO
PHILLIPS UNIV
BOX 2000 UNIV STATION
ENID, OK 73702
(405) 237-4433 EXT 398

LA BAR, MARTIN
CENTRAL WESLEYAN COLL
CENTRAL, SC 29630
(803) 639-2453

SPITZNAGEL, DR JOHN K
DEPT OF MICROBIOLOGY &
IMMUNOLOGY
EMORY UNIV SCHOOL OF
MEDICINE
502 WOODRUFF MEM BLDG
ATLANTA, GA 30322
(404) 727-5947

STANSFIELD, WILLIAM
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2875

VOORHEES, FRANK RAY
DEPT OF BIOLOGY
CENTRAL MISSOURI STATE
UNIV, WCM 306
WARRENSBURG, MO 64093
(816) 429-4933

WOLF, THOMAS M
DEPT OF BIOLOGY
WASHBURN UNIV OF TOPEKA
1700 COLLEGE AVE
TOPEKA, KS 66621
(913) 295-6768

INSTRUCTIONAL DESIGN

HEESTAND, DIANE
LEARNING RESOURCES
MERCER SCH OF MEDICINE
MACON, GA 31207
(912) 744-4026

INTERNAL MEDICINE

BETESH, DR JOEL
LAWRENCE PARK MEDICAL
OFFICE
2000 SPROUL ROAD
BROOMALL, PA 19008
(215) 359-1355

TALLEY, ROBERT C
UNIV OF SOUTH DAKOTA
2501 W 22ND ST
SIOUX FALLS, SD 57101
(605) 339-6790

WAIVERS, LEO E
UNIVERSITY HOSPITAL
NEW JERSEY MED SCH
100 BERGEN ST
ROOM I-247
NEWARK, NJ 07103
(201) 456-6057

LIMNOLOGY

WHALLS, MARVIN J
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-1357

LIVESTOCK PRODUCTION

OLTJEN, J W
DEPT OF ANIMAL SCIENCE
OKLAHOMA STATE UNIV
STILLWATER, OK 74078
(405) 624-6070

MARINE SCIENCE

BOYNTON, DR JOHN E
ST JOSEPH'S COLLEGE
155 ROE BLVD
PATCHOGUE, NY 11772
(516) 654-3200

FORTNER, ROSANNE
OHIO STATE UNIV

0742-3233/88/$0.00 + 2.00

SCHOOL OF NATURAL RESOURCES
2021 COFFEY ROAD
COLUMBUS, OH 43210
(614) 422-2265

SINGLETARY, ROBERT L
DEPT OF BIOLOGY
UNIV OF BRIDGEPORT
BRIDGEPORT, CT 06601
(203) 576-4265

MEDICAL TECHNOLOGY/ ASS'T

GRADY, DAVID V
DEPT OF BIOL SCIENCES
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2883

KLAAS, JUDY C
DEPT OF BIOLOGY
FRAMINGHAM STATE COLL
BOX 2000
FRAMINGHAM, MA 01701
(617) 620-1220 EXT 459

ZEITTER, SHIRLEY
DAVENPORT COLLEGE
415 EAST FULTON
GRAND RAPIDS, MI 49503
(616) 451-3511

MICROANATOMY

FEEBACK, DANIEL
DEPT OF ANATOMICAL SCI
UNIV OKLA HEALTH SCI CTR
PO BOX 26901 BMSB540
OKLAHOMA CITY, OK 73190
(405) 271-2377

MICROBIOLOGY

ALBRITTON, WILLIAM L
DEPT OF MICROBIOLOGY
UNIV OF SASKATCHEWAN
SASKATOON, SK S7N 0W0
CANADA
(306) 966-4306

BAUR, JOHN M
DEPT OF BIOLOGY
BRESCIA COLLEGE
OWENSBORO, KY 42301
(502) 685-3131 EXT 276

CALDWELL, DOUG
DEPTS OF APPLIED MICROBIOLOGY & FOOD SCIENCE
UNIV OF SASKATCHEWAN
SASKATOON, SK S7N 0W0
CANADA
(306) 966-5026

DILLEHAY, DR JANE
DEPT OF BIOLOGY
GALLAUDET COLLEGE
WASHINGTON, DC 20002
(202) 651-5531

DOYLE, JAMES
DEPT OF BIOLOGY
AQUINAS COLLEGE
GRAND RAPIDS, MI 49506
(616) 459-8281 EXT 387

EISENSTARK, A
DEPT OF BIOL SCIENCE
UNIV OF MISSOURI
COLUMBIA, MO 65211
(314) 882-7098

ELDER, DR BETTY
DEPT OF BIOLOGY
GEORGIA SOUTHWESTERN COLLEGE
AMERICUS, GA 31709
(912) 928-1250

GIBSON, LINDA
DEPT OF BIOLOGY
EASTERN WASH UNIV
CHENEY, WA 99004
(509) 359-2845

GRADY, DAVID V
DEPT OF BIOL SCIENCES
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2883

HALL, LEO
PHILLIPS UNIV
BOX 2000 UNIV STATION
ENID, OK 73702
(405) 237-4433 EXT 398

HEIMBROOK, MARGARET E
DEPT OF BIOL SCIENCES
UNIV OF NORTHERN COLO
GREELEY, CO 80639
(303) 351-2644

HODGSON, DR LYNN M
NORTHERN STATE COLLEGE
BOX 673
ABERDEEN, SD 57401
(605) 222-2432

KLAAS, JUDY C
DEPT OF BIOLOGY
FRAMINGHAM STATE COLL
BOX 2000
FRAMINGHAM, MA 01701
(617) 620-1220 EXT 459

KRUSE, ANNA C
CABRINI COLLEGE
RADNOR, PA 19087
(215) 687-2100

NIERLICH, DONALD P
DEPT OF MICROBIOLOGY
UCLA
LIFE SCIENCES 5304
LOS ANGELES, CA 90024
(213) 825-6720

PARKER, CHARLOTTE D
DEPT OF MICROBIOLOGY
SCHOOL OF MEDICINE
UNIV OF MISSOURI M264
COLUMBIA, MO 65212
(314) 882-8152

PRESCOTT, LANSING M
DEPT OF BIOLOGY
AUGUSTANA COLLEGE
29TH AND S SUMMIT
SIOUX FALLS, SD 57197
(605) 336-4719

REDD, MRS THOMASINA
DEPT OF NATURAL SCIENCE
ALDERSON-BROADDUS COLLEGE
BOX 517
PHILIPPI, WV 26416
(304) 457-1700 EXT 243

SABOSKI, ELEANOR M
NEW ENGLAND COLLEGE
HENNIKER, NH 03242
(603) 428-2374

SCHADLER, DANIEL L
DEPT OF BIOLOGY
OGLETHORPE UNIV
4484 PEACHTREE ROAD NE
ATLANTA, GA 30319-2797
(404) 261-1441 EXT 403

SINNAMON, WALT
CENTRAL WESLEYAN COLL
BOX 443
CENTRAL, SC 29630
(803) 639-2453 EXT 356

SOBIESKI, ROD
DEPT OF BIOLOGY
EMPORIA STATE UNIV
1200 COMMERCIAL
EMPORIA, KS 66801
(316) 343-1200 EXT 5620

SOTTNEK, HENRY M
DEPT OF MED TECHNOLOGY
GEORGIA STATE UNIV
ATLANTA, GA 30303
(404) 658-3034

SPENCE, LESLIE
18 INEZ COURT
WILLOWDALE, ONT M2M 1C2
CANADA
(416) 595-3079

SPITZNAGEL, DR JOHN K
DEPT OF MICROBIOLOGY & IMMUNOLOGY
EMORY UNIV SCH MED
502 WOODRUFF MEM BLDG
ATLANTA, GA 30322
(404) 727-5947

STONE, LARRIE E
DANA COLLEGE
BLAIR, NE 68008
(402) 426-4101 EXT 229

STRATTON, LEWIS P
DEPT OF BIOLOGY
FURMAN UNIV
GREENVILLE, SC 29613
(803) 294-3249

WALKER, RICHARD
STERLING COLLEGE
STERLING, KS 67579
(316) 278-2173

WILHELM, DALLAS
DEPT OF BIOLOGY
HASTINGS COLLEGE
HASTINGS, NE 68901
(402) 463-2402 EXT 264

MODELING

WATROUS, JAMES
DEPT OF BIOLOGY
ST JOSEPH'S UNIV
PHILADELPHIA, PA 19131
(215) 879-7342

MOLECULAR BIOLOGY

BERGQUIST, BART
DEPT OF BIOLOGY
UNIV OF NORTHERN IOWA
CEDAR FALLS, IA 50614
(319) 273-2723

BOND, CLIFFORD
DEPT OF MICROBIOLOGY
MONTANA STATE UNIV
BOZEMAN, MT 59717
(406) 994-4130

DILLEHAY, DR JANE
DEPT OF BIOLOGY
GALLAUDET COLLEGE
800 FLORIDA AVE NE
WASHINGTON, DC 20002
(202) 651-5531

GORMAN, MARK
BALDWIN-WALLACE COLL
LIFE SCIENCE BLDG
BEREA, OH 44017
(216) 826-2217

HARLEY, CALVIN B
DEPT OF BIOCHEMISTRY
McMASTER UNIV
HAMILTON, ONT L8N 3Z5
CANADA
(416) 525-9140 EXT 2040

KLEINSMITH, LEWIS J
DEPT OF BIOLOGY
UNIV OF MICHIGAN
2056 NATURAL SCIENCE
ANN ARBOR, MI 48109-1048
(313) 763-3290

PRESCOTT, LANSING M
DEPT OF BIOLOGY
AUGUSTANA COLLEGE
29TH AND S SUMMIT
SIOUX FALLS, SD 57197
(605) 336-4719

REDD, MRS THOMASINA
DEPT OF NATURAL SCIENCE
ALDERSON-BROADDUS COLL
PHILIPPI, WV 26416
(304) 457-1700 EXT 243

WOLF, THOMAS M
DEPT OF BIOLOGY
WASHBURN UNIV OF TOPEKA
1700 COLLEGE AV
TOPEKA, KS 66621
(913) 295-6768

MOLECULAR GENETICS

HALL, LEO
PHILLIPS UNIV
BOX 2000 UNIV STATION
ENID, OK 73702
(405) 237-4433 EXT 398

NIERLICH, DONALD P
DEPT OF MICROBIOLOGY
UCLA
LIFE SCIENCES 5304
LOS ANGELES, CA 90024
(213) 825-6720

NATURAL HISTORY

GAMBS, ROGER
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2551

NEUROANATOMY

MEYERS, PAUL E
DEPT OF BIOL CHEM & STRUCTURE
THE CHICAGO MED SCH
3333 GREEN BAY RD
NORTH CHICAGO, IL 60064
(312) 578-3000 EXT 458

NEUROBIOLOGY/NEUROSCIENCE

BUCHHOLZ, ROBERT H
DEPT OF BIOLOGY

0742-3233/88/$0.00 + 2.00

MONMOUTH COLLEGE
MONMOUTH, IL 61462
(309) 457-2350

NEAFSEY, E J
DEPT OF ANATOMY
LOYOLA UNIV MED CTR
MAYWOOD, IL 60153
(312) 531-3355

RALSTON, H J
DEPT OF ANATOMY S-1334
UNIV CA SAN FRANCISCO
SAN FRANCISCO, CA 94143
(415) 476-1861

STOUT, JOHN
DEPT OF BIOLOGY
ANDREWS UNIV
BERRIEN SPRINGS, MI 49104
(616) 471-3243

YORK, DR DONALD H
DEPT OF PHYSIOLOGY
UNIV OF MISSOURI
MA415 MEDICAL SCI BLDG
COLUMBIA, MO 65212
(314) 882-7168

NURSING

ABBATE, JUDITH
COLLEGE OF NURSING
UNIV OF RHODE ISLAND
KINGSTON, RI 02881
(401) 792-2766

BENEDICT, DR SUSAN
209 MOUNTAIN RIDGE DRIVE
HUNTSVILLE, AL 35801
(205) 536-7101

BUDIN, WENDY
COLLEGE NURSING
SETON HALL UNIV
SOUTH ORANGE, NJ 07079
(201) 761-9299

CLAUS, SACHIKO K
DEPT OF NURSING
SAGINAW VALLEY STATE
COLLEGE
UNIVERSITY CTR, MI 48710
(517) 790-4129

DREHER, MARY ANN
25034 SHEFFIELD ROAD
GLEN ELLYN, IL 60137

GARDINER, MARY
RED DEER COLLEGE
RED DEER, ALBERTA T5N 5H5
CANADA
(403) 342-3362

GROBE, S J
SCHOOL OF NURSING
UNIV OF TEXAS
AUSTIN, TX 78701
(512) 471-7311

HASKIN, DOUGLAS E
SCHOOL OF NURSING
UNIV TEXAS MEDICAL
BRANCH R-49
GALVESTON, TX 77550
(409) 761-1577

HODSON, KAY E
SCHOOL OF NURSING CN355
BALL STATE UNIV
MUNCIE, IN 47306
(317) 285-5583

KRISTENSEN, KAREN
TRI-COLLEGE UNIV OF NURS
NORTH DAKOTA STATE UNIV
FARGO, ND 58105
(701) 237-8170

KUREN, KATHERINE
COLLEGE OF NURSING
SETON HALL UNIV
SOUTH ORANGE, NJ 07079
(201) 761-9303

LARSON, DONNA
KIRKOF SCHOOL OF NURSING
GRAND VALLEY STATE COLL
ALLENDALE, MI 49401
(616) 895-3540

LIBEY, TERRY
DEPT OF HEALTH CAREERS
LANSING COMMUNITY
COLLEGE
419 N CAPITOL AVE
LANSING, MI 48901-7211

LOUIS, MARGARET
DEPT OF NURSING
UNIV OF NEVADA, LAS VEGAS
LAS VEGAS, NV 89154

MIKAN, KATHLEEN
SCHOOL OF NURSING
UNIV ALABAMA AT
BIRMINGHAM
BIRMINGHAM, AL 35294
(205) 934-4837

MURRAY, LAURIE R
COLLEGE OF NURSING
UNIV OF RHODE ISLAND
KINGSTON, RI 02881-0814
(401) 792-2766

RONALD, DR JUDITH
SCHOOL OF NURSING
SUNY AT BUFFALO
BUFFALO, NY 14214
(716) 831-3045

SCHARF, MARY ANN
COLLEGE OF NURSING
SETON HALL UNIV
SOUTH ORANGE, NJ 07079
(201) 761-9293

SINCLAIR, VAUGHN G
VANDERBILT UNIV SCHOOL
OF NURSING
NASHVILLE, TN 37235
(615) 322-2813

SKIBA, DIANE
23 HOLMES ST
DEDHAM, MA 02026
(617) 461-0276

THEDE, LINDA Q
36203 DERBY DOWNS
SOLON, OH 44139
(216) 248-3537

WHITE, JOYCE E
UNIV OF PITTSBURGH
426 VICTORIA BLDG
PITTSBURGH, PA 15261
(412) 624-3835

NUTRITION

DICKINSON, WINIFRED
DEPT OF BIOLOGY
UNIV OF STEUBENVILLE
STEUBENVILLE, OH 43952
(614) 283-3771

HARROLD, ROBERT
DEPT OF ANIM & RANGE SCI
NORTH DAKOTA STATE UNIV
FARGO, ND 58105
(701) 237-7659

HESTON, W M
CTR FOR NATURAL SCIENCES
NEW YORK INST TECH
OLD WESTBURY, NY 11568
(516) 686-7665

HU, CHING YUAN
DEPT OF ANIMAL SCIENCE
OREGON STATE UNIV
CORVALLIS, OR 97331
(503) 754-4761

OLTJEN, J W
DEPT OF ANIMAL SCIENCE
OKLAHOMA STATE UNIV
STILLWATER, OK 74078
(405) 624-6670

SCHNEIWEISS, JEANNETTE W
DEPT OF BIOLOGY
HOFSTRA UNIV
HEMPSTEAD, NY 11550
(516) 560-5521

SHORT, SARAH H
SYRACUSE UNIV
112 SLOCUM HALL
SYRACUSE, NY 13244-1250
(315) 423-2386

WAGNER, MARTIN J
DEPT OF BIOCHEMISTRY
BAYLOR COLLEGE OF
DENTISTRY
DALLAS, TX 75246
(214) 828-8261

ORAL HISTOLOGY

FEEBACK, DANIEL
DEPT OF ANAT SCIENCE
UNIV OF OKLAHOMA HEALTH
SCIENCE CENTER
PO BOX 26901 BMSB540
OKLAHOMA CITY, OK 73190
(405) 271-2377

ORAL PATHOLOGY

ABBEY, LOUIS M
DEPT OF ORAL PATHOLOGY
VIRGINIA COMMONWEALTH
UNIV
BOX 566 MCV STATION
RICHMOND, VA 23298
(804) 786-0547

FINKELSTEIN, MICHAEL
DEPT OF ORAL PATHOLOGY
COLLEGE OF DENTISTRY
UNIV OF IOWA
IOWA CITY, IA 52242
(319) 353-7370

ORNITHOLOGY

CYR, ANDRE
DEPT OF BIOLOGY
UNIV OF SHERBROOKE
SHERBROOKE, QUEBEC
CANADA J1K 2R1
(819) 821-7074

PARRISH, DR JOHN
DEPT OF BIOLOGY
EMPORIA STATE UNIV
EMPORIA, KS 66801
(316) 343-1200

VERCH, RICHARD
DEPT OF BIOLOGY
NORTHLAND COLLEGE
ASHLAND, WI 54806
(715) 682-4531 EXT 335

PARASITOLOGY

BAUR, JOHN M
DEPT OF BIOLOGY
BRESCIA COLLEGE
OWENSBORO, KY 42301
(502) 685-3131 EXT 276

HILTON, DONALD FJ
DEPT OF BIOL SCIENCES
BISHOP'S UNIV
LENNOXVILLE QUE J1M 1Z7
CANADA
(819) 569-9551

PATHOLOGY

FEEBACK, DANIEL
DEPT OF ANAT SCIENCE
UNIV OF OKLAHOMA HEALTH
SCIENCE CENTER
PO BOX 26901 BMSB540
OKLAHOMA CITY, OK 73190
(405) 271-2377

GANDER, G WM
DEPT OF PATHOLOGY
MEDICAL COLL OF VIRGINIA
BOX 662
RICHMOND, VA 23298
(804) 786-7719

JOTHY, DR SERGE
DEPT OF PATHOLOGY
McGILL UNIV
3775 UNIVERSITY ST
MONTREAL, QUEBEC H3A 2B4
CANADA
(514) 842-1231

KLAAS, JUDY C
DEPT OF BIOLOGY
FRAMINGHAM STATE COLL
BOX 2000
FRAMINGHAM, MA 01701
(617) 620-1220 EXT 459

LEIGHTON, FREDERICK A
DEPT OF VET PATHOLOGY
UNIV OF SASKATCHEWAN
SASKATOON, SK S7N 0W0
CANADA
(306) 966-7293

MASSEY, K LORNE
DEPT OF PATHOLOGY
COLLEGE OF MEDICINE
UNIV OF SASKATCHEWAN
SASKATOON, SASK S7N 0W0
CANADA
(306) 966-2167

McMANNO, BRUCE
DEPT OF PATHOLOGY
UNIV NEBRASKA MEDICAL CENTER
42ND & DEWEY AVE
OMAHA, NE 68105
(402) 559-5192

PALMER, KENNETH C
DEPT OF PATHOLOGY
WAYNE STATE UNIV SCHOOL OF MEDICINE
540 E CANFIELD
DETROIT, MI 48201
(313) 577-5152

YOSHIMURA, MICHAEL A
DEPT OF BIOLOGICAL SCIENCE
CAL POLYTECH STATE UNIVERSITY
SAN LUIS OBISPO, CA 93407
(805) 546-2466

PEDIATRICS

WINTER, ROBERT J
CHILDREN'S MEMORIAL HOSP
2300 CHILDREN'S PLAZA
CHICAGO, IL 60614
(312) 880-4196

PHARMACOLOGY

BEHEL, MARGARET A
ROUTE 3 BOX 77
PHIL CAMPBELL, AL 35585
(205) 993-5331

CONAHAN, SHAWN T
DEPT OF PHYSIOLOGY
LOUISIANA STATE UNIV MED CENTER
1901 PERDIDO ST
NEW ORLEANS, LA 70112
(504) 582-5783

GWINN, DR JOHN F
DEPT OF BIOLOGY
UNIV OF AKRON
AKRON, OH 44325
(216) 375-7160

HAGEN, STANLEY VON
DEPT OF PHARMACOLOGY
NEW JERSEY MEDICAL SCHOOL
NEWARK, NJ 07103
(201) 456-4385

SPECHT, PHILIP C
PHARMACOLOGY DEPT
UPR MEDICAL SCHOOL
GPO BOX 5067
SAN JUAN, PR 00936
(809) 758-2525 EXT 1300

SPYKER, D A
UNIV OF VIRGINIA SCHOOL OF MEDICINE
BOX 484 MEDICAL CENTER
CHARLOTTESVILLE, VA 22908

KEEPING ABREAST OF THE LITERATURE

The following citations are presented as part of a quarterly feature in CLSE designed to help readers become aware of current literature pertinent to computer applications in life science education.

Beyon RJ: Computers in biochemical education: MBT-NET, the Liverpool biochemistry/microbiology teaching network. Biochem Soc Trans 15(3):349-351, 1987.

Boulet M: Educational software design using a diagnostic approach. Computers and Education 11(3):219-227, 1987.

Clark D: Aspects of menu design. J Comp Assisted Learning 2(3):172-177, 1986.

De Bloois M: Anticipating compact disc-interactive (CD-I): Ten guidelines for prospective authors. Educ Tech 27(4):25-27, 1987.

Douglass SE: Computers and the copyright law. Educational Horizons 66(1):46-48, 1987.

Garrett TJ et al: A comparison of computer-assisted instruction and tutorials in hematology and oncology. J Med Educ 62(11):918-922, 1987.

Gwinnett A: Computers in training nurses? Br J Healthc Comput 3(6):21, 23, 25, 1986.

Hosie P: Adopting interactive videodisc technology for education. Educ Tech 27(7):5-10, 1987.

Johnston R et al: Computers in respiratory therapy. AARC Times 11(5):18, 1987.

Kunstaetter R: Intelligent physiologic modelling: an application of knowledge based systems technology to medical education. Comput Methods Programs Biomed 24(3):213-225, 1987.

Lay C et al: The legal implications of repurposing videodiscs. Videodisc Monitor 5(7):23, 1987.

Miller K et al: Audio-enhanced computer-assisted learning in science teaching. Biochem Soc Trans 15(3):351-354, 1987.

Moshinskie J: Terminally trained... computer-assisted instruction. Emergency 19(8):42-43, 58-59, 1987.

Park O et al: Conventional CBI versus intelligent CAI: suggestions for the development of future systems. Educ Tech 27(5):15-21, 1987.

Rambally GK: The AI approach to CAI. Computing Teacher 13(7):39-42, 1986.

Rambally GK et al: Human factors in CAI design. Comput Educ 11(2):149-153, 1987.

Raymond J: The computerized overhead projector. Computers and Education 11(3):181-195, 1987.

Sandoval VA et al: A comparison of four simulation and instructional methods for endodontic review. J Dent Educ 51(9):532-538, 1987.

Schwirian PM: Evaluation research in computer-based instruction. Dilemmas and directions. Comput Nurs 5(4):128-131, 1987.

Strack G: The computer takes a field trip. Comput Teach 13(7):12-17, 1986.

Suzuki K: A short-cycle approach to CAI development: three stage authoring for practitioners. Educ Tech 27(7):19-24, 1987.

Tennyson RD: MAIS: An educational alternative of ICAI. Educ Tech 27(5):22-28, 1987.

Thomson I et al: Interactive videodiscs in the life sciences: the use of 'generic' discs in the teaching of cell biology. Biochem Soc Trans 15(3):354-356, 1987.

Troutner J: Computer literacy. Problem solving software for science classes. J Comp Math Sci Teach 6(3):9-11, 1987.

0742-3233/88/$0.00 + 2.00

AIMS AND SCOPE

The goal of *Computers in Life Science Education* is to provide a means of communication among life science educators who anticipate or are currently employing the computer as an educational tool. The range of content includes, but is not limited to, articles focusing on computer applications and their underlying philosophy, reports on faculty/student experiences with computers in teaching environments, and software/hardware reviews in both basic science and clinical education settings.

INVITATION TO CONTRIBUTORS

Articles consistent with the goals of *Computers in Life Science Education* are invited for possible publication in the newsletter.

PREPARATION AND SUBMISSION OF MATERIAL

Articles submitted for publication should not exceed 2000 words and should be typewritten, double spaced, with wide margins. The original and two copies including two sets of figures and tables should be sent to the Editor: Dr. Harold Modell, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

Title page should include full title, list of authors, academic or professional affiliations, and complete address and phone number of the corresponding author.

Illustrations should be submitted as original drawings in India ink or sharp, unmounted photographs on glossy paper. The lettering should be such that it can be legible after reduction (width of one column = 5.7 cm).

Reference style and form should follow the "number system with references alphabetized" described in the Council of Biology Editors Style Manual. References should be listed in alphabetical order by the first author's last name, numbered consecutively, and cited in the text by these numbers.

RESPONSIBILITY AND COPYRIGHT

Authors are responsible for accuracy of statements and opinions expressed in articles. All authors submitting manuscripts will be sent a copyright transfer form to complete. The completed form must be returned before the work will be published.

SUBSCRIPTION INFORMATION

Computers in Life Science Education is published monthly by National Resource for Computers in Life Science Education, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Subscription rate is $30.00 for 12 issues, including postage and handling in the United States and Canada. Add $20.00 for postage (airmail) in Mexico and Europe and $23.00 for the rest of the world.

This newsletter has been registered with the Copyright Clearance Center, Inc. Consent is given for copying of articles for personal or internal use, or for the personal or internal use of specific clients. This consent is given on the condition that the copier pay through the Center the per-copy fee stated in the code on the first page for copying beyond that permitted by the US Copyright Law. If no code appears on an article, the author has not given broad consent to copy and permission to copy must be obtained directly from the author. This consent does not extend to other kinds of copying, such as for general distribution, resale, advertising and promotional purposes, or for creating new collective works.

Address orders, changes of address, and claims for missing issues to NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Claims for missing issues can be honored only up to three months for domestic addresses and six months for foreign addresses. Duplicate copies will not be sent to replace ones undelivered due to failure to notify NRCLSE of change of address.

Address editorial correspondence to Harold I. Modell, PhD, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. (BITNET MODELL@UWALOCKE)

POSTMASTER: Send address changes to *Computers in Life Science Education*, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

0742-3233/88/$0.00 + 2.00

VOLUME 5 NUMBER 4, APRIL 1988 CLSEE3 5(4) 25-32, 1988 ISSN 0742-3233

COMPUTERS IN LIFE SCIENCE EDUCATION

HAROLD I. MODELL
Department of Radiology
University of Washington
Seattle, Washington

MARCEL BLANCHAER
Department of Biochemistry
Faculty of Medicine
University of Manitoba
Winnipeg, Manitoba

THEODORE J. CROVELLO
Graduate Studies and Research
California State University, Los Angeles
Los Angeles, California

JAMES W. ECKBLAD
Department of Biology
Luther College
Decorah, Iowa

TSEGAYE HABTEMARIAM
School of Veterinary Medicine
Tuskegee University
Tuskegee, Alabama

DONNA LARSON
School of Nursing
Grand Valley State College
Allendale, Michigan

TERRY M. MIKITEN
Graduate School of Biomedical Sciences
University of Texas Health Science Center
San Antonio, Texas

JAMES E. RANDALL
Department of Physiology
Indiana University
Bloomington, Indiana

PATRICIA SCHWIRIAN
College of Nursing
Ohio State University
Columbus, Ohio

RICHARD STULL
College of Pharmacy
University of Arkansas
Little Rock, Arkansas

JAMES W. WOODS
Lister Hill National Center
for Biomedical Communications
National Library of Medicine
Bethesda, Maryland

DOROTHY WOOLEY-McKAY
Department of Biology
Glendale Community College
Glendale, Arizona

GLEN YOSHIDA
Department of Life Sciences
Los Angeles Southwest College
Los Angeles, California

NRCLSE

CONTENTS

APPLE //e MEDIATED WORKSTATIONS IN THE UNDERGRADUATE PHYSIOLOGY 25
Michael A. Kolitsky

CLSE 1987-88 COLLEAGUE DIRECTORY - PART III 29

APPLE //e MEDIATED WORKSTATIONS IN THE UNDERGRADUATE PHYSIOLOGY LABORATORY

Michael A. Kolitsky
Department of Biological Sciences, California Lutheran University, Thousand Oaks, California

Several years ago, the National Science Foundation established the College Science Instrumentation Program (CSIP) to upgrade laboratory instrumentation in undergraduate science education. I was the principle investigator for a CSIP award in 1985 (#CSI-8557398) that permitted me to assemble five Apple //e-mediated workstations for use in my physiology laboratories. The workstation concept exploited the idea that a microcomputer, when linked to an appropriate environmentally sensitive interface, could be transformed into a versatile, data-gathering laboratory instrument.[2,3] I developed software to permit use of the Apple //e monitor screen as a strip chart recorder and, when the desired screen image was obtained, students could employ a dot-matrix printer to make hard copies of the graphics screen for their lab notebooks. By simply changing the interface or the controlling software, a single workstation could be made to act like many single-function laboratory instruments. For example, my students have used an inexpensive, self-constructed photosensitive interface to transform the Apple //e into a transmission densitometer to study red blood cell hemolysis,[3] a kymograph to investigate frog skeletal muscle contraction,[3] a pneumograph to investigate human

0742-3233/88/$0.00 + 2.00

respiratory mechanics and as a device to measure human reaction time in response to audio or visual stimuli. Several types of commercially available interfaces were also employed to allow the Apple //e to act as a pH meter (HRM Software, 175 Tompkins Ave, Pleasantville, New York 10570) and a digital oscilloscope (W.H. Nail Co, 1096 C oro Dam Blvd., Oroville, CA 95965) for electrophysiological studies. For an excellent description of the use of the Apple as a digital storage oscilloscope, I refer you to a report by Mary Coyne.[1]

In this report, I would like to focus on the photosensitive interface and its application in the undergraduate physiology laboratory. The simplicity of the photosensitive interface may be seen in the diagram of the schematics shown in Figure 1. An FPT-100 phototransistor is used to measure light intensity by changes in resistance. A 16 pin Dual Input Plug (DIP) is used to connect the collector pin and the emittor pin of the phototransistor to the +5 Volt and ground pins of the Apple game I/O connector. The DIP and phototransistor plus the "breadboard" (microcircuit board) which hold the components cost under $20.00 to construct and can be obtained from local or regional electronics suppliers.

SOFTWARE DESIGN

Applesoft BASIC was used to write the data sampling and display programs for all experiments in this report. These programs cause the monitor screen to act like a strip chart recorder by drawing a single trace across the high resolution graphics screen from left to right. In order to do this in BASIC, the statement Y = PDL(0) was used to sample the interface resistance reading and return a value ranging from 0 to 255. The value for Y determines the pixel to be lit on the vertical axis of the graphics screen. The movement of the trace from left to right is driven by FOR-NEXT loop statements that increase the value of X by one each time the loop is executed. When the statement, HPLOT X,Y, is included within the FOR-NEXT loop, pixels are lit in sequence from left to right to simulate a strip chart recording.

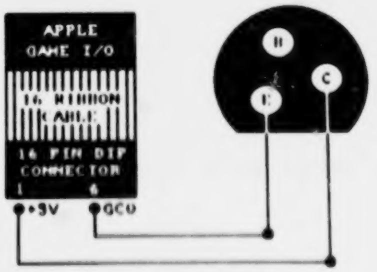


FIGURE 1. Schematic for photosensitive interface. A view of the underside of an FPT-100 phototransistor (upper right) showing placement of the pins and their connection to the DIP connector. E=emitter pin, B=base pin, C=collector pin. Pin 1 of the DIP is the +5 volt source, and pin 6 is the ground (GC0) connection.

A Grappler card in expansion slot 4 connects to a dot-matrix printer and gives students the option to print the high resolution graphics screen in the desired format. Selected screens may also be saved in floppy disk files for review at a later time.

STUDENT APPLICATIONS

Students used the photosensitive interface as a transmission densitometer for two types of experiments with red blood cells (RBCs). First, slow hemolysis kinetics of RBCs were followed after introduction of the RBCs into solutions of 0.5 M urea, glycerol or glucose.[3] In the second type of experiment, students examined the effects of tonicity on RBC shape and size. For both experiments, a 3 Volt miniature lamp was positioned so that its light traveled through a test tube containing the RBC suspension before falling on the phototransistor. The results from a typical slow hemolysis experiment in which an RBC suspension was introduced into a solution of 0.5M glycerol can be seen in Figure 2. When RBCs were added, the trace immediately moved upward indicating less light falling on the phototransistor due to an increase in light scattered by the RBCs. Thereafter, the slow downward trace movement to the baseline gave a measure of hemolysis time and indicated that more light reached the phototransistor as light scattering decreased due to RBC swelling and eventual hemolysis. Hemolysis time under these conditions also indicates how fast molecules pass through the RBC membrane. Students find that urea solutions hemolyze RBCs in under 5 seconds, glycerol solutions exhibit hemolysis times around 30 seconds, and in glucose solutions, hemolysis is still incomplete even after 90 seconds. Students may conclude that there is a relationship between molecular size and the ability to pass through a membrane.

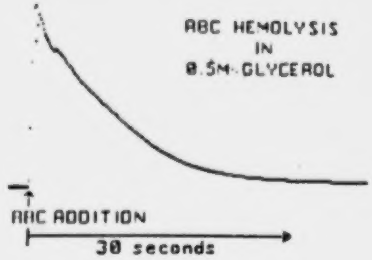


FIGURE 2. Red blood cell slow hemolysis kinetics following addition to 0.5M glycerol. A Digi-View digitizing system (Newtek, Inc., 701 Jackson Suite B3, Topeka KS 66603) was used to transfer the original results from the Apple //e monitor to an Amiga 1000 computer serving as a low cost graphics workstation to permit addition of explanatory text using an Electronic Arts Deluxe Paint program. A photograph was then made using a Polaroid Palette system. All other figures and the single table were produced using the Amiga graphics workstation.

The results of tonicity studies in which RBCs were suspended in different NaCl concentrations are shown in Table 1. Transmitted light decreases as the salt concentration increases to 2%. By observing RBC morphology with

Table 1. Use of photosensitive interface to measure light transmitted through RBCs suspended in different salt concentrations. Higher interface readings indicate more light falling on the phototransistor.

TRANSMISSION DENSITOMETRY

LIGHT TRANSMITTED BY RBC'S IN DIFFERENT CONCENTRATIONS OF SODIUM CHLORIDE

SOLUTION	INTERFACE READING
DISTILLED H_2O	237
0.43% NaCl	213
0.85% NaCl	177
2.0% NaCl	120

the light microscope, students can also relate RBC shape with its ability to transmit and scatter light.

The photosensitive interface was also utilized as an updated version of a kymograph to study frog muscle contraction. A typical kymograph arrangement for muscle study was employed except that a phototransistor hung from the tip of the muscle lever instead of an ink writing stylus, and an Apple //e monitor replaced the revolving drum. The phototransistor extended into a short length of PVP (polyvinylpropylene) pipe and was illuminated by a 3 Volt miniature lamp positioned at the bottom. During contraction, the muscle lifted the lever and phototransistor away from the light source, and when the muscle relaxed, the phototransistor returnd to its original position. The detected change in light intensity was displayed on the Apple //e monitor screen. The results in Figure 3 were obtained by measuring individual muscle contraction-relaxation responses to a series of electrical stimuli of increasing voltage. The software was designed to wait for the student team to get everything ready for stimulation. When ready, the team signals the program to enter a 15 second period during which they stimulate the muscle with the selected voltage. If the muscle contracts, the monitor screen displays the detected light change as a single, vertical line above the baseline. At the end of 15 seconds, the program moves the baseline to the right a short distance and waits again for the student team to prepare the muscle for the next voltage stimulus.

The strip chart recorder mode was used to study muscle contraction by increasing the frequency of stimulation with supramaximal threshold voltage. Selected results are shown in Figure 4. As with the traditional kymograph, individual muscle contraction-relaxation cycles are observed at low frequencies of stimulation (Figure 4A), and complete tetanus is attained at higher stimulation frequencies (Figure 4D).

The strip chart recorder mode software may also be used with a Marey tambour for pneumographic study of human breathing mechanics. Again, a typical kymographic setup was employed in which a bellows pneumograph was strapped around the subject's chest wall and attached to the Marey tambour. The major difference was that measurements were being made by a phototransistor hung from the tip of the lever resting on the tambour diaphragm. Typical experimental results may be seen in Figure 5. The upper trace presents a resting breathing rate and is followed by the middle trace which was made while the subject held his breath for over a minute. The lowest trace demonstrates the expected increase in the breathing rate and depth of inspiration that follows a prolonged breath hold. The response of human breathing mechanics under a variety of conditions such as hyperventilation, rebreathing of exhaled air, or during speech may also be obtained for a more complete study of the physiological conditions governing rate and depth of breathing.

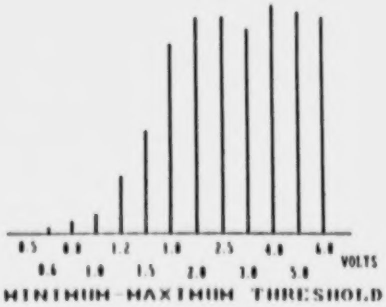


FIGURE 3. Response of frog gastrocnemius muscle to increasing voltage stimuli as measured by the photosensitive interface when used with a kymograph setup.

The photosensitive interface may also be utilized to measure human reaction time to audio or visual stimuli. As a visual stimulus, the subject is asked to respond to the disappearance of a square drawn on the graphics screen by pressing a switch that turns on a small light near the photosensitive transistor. The software measures the time from the disappearance of the square to the detection of light by the phototransistor. For the audio cue, the subject is asked to respond at the time a computer generated tone stops. The time before the square disappears or the tone stops is variable and is dependent on a value obtained from a random number generator. Reaction time may be measured for both the hand and the foot and for differences observed in response to either audio or visual cues.

TIME AND DISTANCE CONSIDERATIONS

The accuracy of time measurement using FOR-NEXT loops must be considered when using the game I/O as the entry site for signals from the photosensitive interface. I utilized a self-built real time clock interface connect-

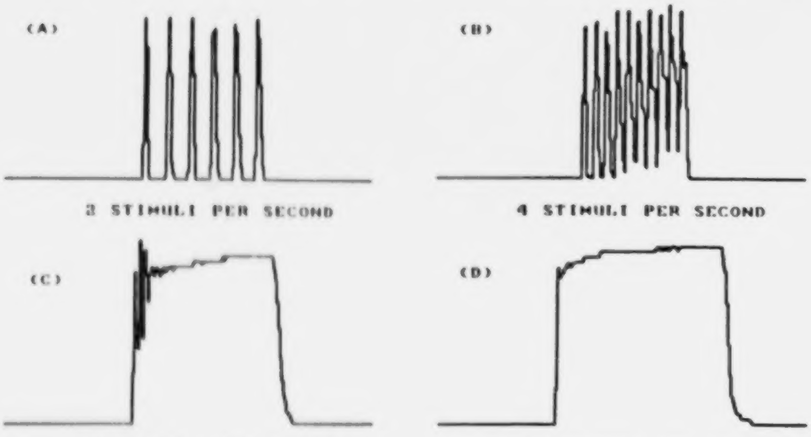


FIGURE 4. Four separate screens (A-D) demonstrating the response of frog gastrocnemius muscle to supramaximal voltage stimuli presented at different frequencies. Strip chart recorder mode software used with the photosensitive interface in the kymograph setup.

0742-3233/88/$0.00 + 2.00

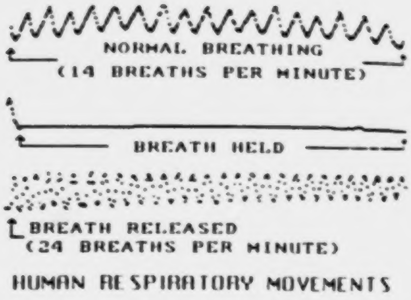


FIGURE 5. Photosensitive interface used as a pneumograph to study human respiratory movements. Strip chart recorder mode software modified to permit the sequential recording of three traces on one screen.

ed to one of the Apple expansion slots to measure, within 0.1 second, the time the trace took to traverse the screen at different light intensities. The results, shown in Figure 6, indicate a linear relationship between trace time and light intensity. At the two extremes of saturating light and total darkness, there is about a 7% difference in trace time indicating that the FOR-NEXT loop timing method collects data in a *near time* rather than *real time* mode. For many experiments at the undergraduate level, near time data collection may be acceptable if it does not compromise student interpretation of results (eg, muscle contraction data in Figures 3 and 4). However, when real time data collection is essential, an external clock interface must be utilized. For a more detailed discussion of analog-digital interfaces and timing considerations, see the article written by Richard Olivo.[4]

For those experiments in which the phototransistor is moved away from the light source, the collected data are not an accurate estimation of the actual distance of the phototransistor from the light source. The error exists because no correction is made to account for the physical fact that light intensity decreases with the square of the distance from the light source. This is reflected in the results shown in Figure 7 in which light intensity measured via the phototransistor is plotted as a function of the phototransistor distance from the light source. The problem can be corrected, however, by referring to a standard curve as shown in Figure 7 to transform the intensity reading into a true distance measurement.

CONCLUSION

The CSIP award supported the assembly of five workstations. Each station serves from three to four students and increases greatly student access to instrumentation. The cost per station was considerably less than the funds that would be needed to purchase each of the single function instruments separately. The multifunctional nature of the Apple //e-mediated workstation coupled with its lower cost when compared to traditional instrumentation offers instructors the opportunity to upgrade undergraduate physiology laboratory instrumentation in a cost effective manner without sacrificing the quality of the laboratory learning experience.

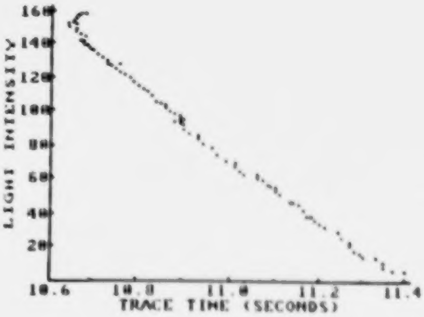


FIGURE 6. Comparison of time for the trace to move from left to right across the monitor screen at different light intensities. Trace time was measured accurately to 0.1 second with a self-built clock interface connected to one of the Apple expansion slots.

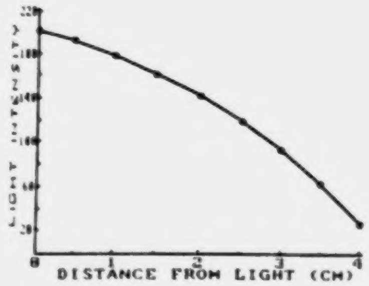


FIGURE 7. Comparison of light intensity reading from the interface with distance of the phototransistor from light source. This particular standard curve was obtained with a phototransistor hanging down from the tip of a kymograph muscle lever into a short length of PVP pipe. A 3 volt miniature lamp was positioned at the bottom of the pipe to serve as a light source.

REFERENCES

1. Coyne, MD. Substitution of apple computers for storage oscilloscopes and polygraphs. Computers In Life Science Education 2:81-86, 1985.
2. Esch HE, and JD McMillen. Microcomputers in undergraduate physiology laboratories. Collegiate Microcomputer 2:151-157, 1984.
3. Kolitsky, MA. Microcomputer applications in biology: using your Apple II plus or //e as a laboratory instrument. Proceedings of the Western Educational Computing Conference. pp193-197, 1984.
4. Olivo, RF. Selecting an analog-digital interface: a tutorial. Computers In Life Science Education 3:89-93, 1986.

0742-3233/88/$0.00 + 2.00

CLSE 1987-88 COLLEAGUE DIRECTORY – PART III

The primary goal of the National Resource for Computers in Life Science Education (NRCLSE) is to cultivate collaborative efforts among life science faculty interested in using the computer as a teaching tool.

The listing that follows is a continuation of the 1987-88 directory published in the February and March issues of CLSE. It is updated from the 1986-87 directory and was drawn primarily from respondents to questionnaires printed in CLSE. It is intended to help readers identify colleagues with common interest areas.

The listings are arranged by the content areas identified in response to the question, "What content areas do you teach?" As a result, entries may appear under more than on heading.

Although every attempt has been made to ensure that the information is current and correct, it is likely that some errors appear in this list. We apologize in advance for any inconveniences that may arise due to such oversights.

If you are aware of other colleagues that should be listed, please send the pertinent information (name, address, phone number, BITNET address, teaching content area) to NRCLSE, Mail Stop RC-70, Univ. of Washington, Seattle, WA 98195 or let us know via BITNET. NRCLSE's BITNET address is MODELL@UWALOCKE.

PHYSIOLOGY

ABRAHAMS, V C
DEPT OF PHYSIOLOGY
QUEEN'S UNIVERSITY
KINGSTON, ONTARIO K7L 3N6
CANADA
(613) 547-3022

AMLANER, CHARLES J Jr
DEPT OF ZOOLOGY
UNIV OF ARKANSAS
FAYETTEVILLE, AR 72701

BASHOR, DAVID P
DEPT OF BIOLOGY
UNIV N CAROLINA AT
CHARLOTTE
CHARLOTTE, NC 28223
(704) 597-4047

BAUR, JOHN M
DEPT OF BIOLOGY
BRESCIA COLLEGE
120 WEST SEVENTH ST
OWENSBORO, KY 42301
(502) 685-3131 EXT 276

BENNETT, THOMAS E
DEPT OF BIOLOGY
BELLARMINE COLLEGE
NEWBURG ROAD
LOUISVILLE, KY 40205
(502) 452-8198

BERG, VIRGINIA
DEPT OF BIOLOGY
UNIV OF NORTHERN IOWA
CEDAR FALLS, IA 50614
(319) 273-2770

BERGQUIST, BART
DEPT OF BIOLOGY
UNIV OF NORTHERN IOWA
CEDAR FALLS, IA 50614
(319) 273-2723

BEUMER, RONALD J
BIOLOGY DEPT
ARMSTRONG STATE COLLEGE
SAVANNAH, GA 31419
(912) 927-5314

BORQUEZ, DR RICARDO LEON
UNIV AUTO GUADALAJARA
LOMAS DEL VALLE 1ERA
SECC
GUADALAJARA
MEXICO JAL 1-440

BROOKE, Dr JOHN D
NEUROPHYSIOLOGY LAB
UNIVERSITY OF GUELPH
SCHOOL OF HUMAN BIOLOGY
GUELPH, ONTARIO N1G 2W1
CANADA
(519) 824-4120 EXT 3416

BROWN, DAVID E
DEPT OF ANIMAL SCIENCE
UNIV OF NEVADA AT RENO
RENO, NV 89557-0004
(702) 784-1629

BRUMLEVE, STANLEY J
DEPT OF PHYSIOLOGY
SCHOOL OF MEDICINE
UNIV OF NORTH DAKOTA
GRAND FORKS, ND 58202
(701) 777-3974

BUCHHOLZ, ROBERT H
DEPT OF BIOLOGY
MONMOUTH COLLEGE
MONMOUTH, IL 61462
(309) 457-2350

BURNS, DR THOMAS A
DEPT OF BIOLOGY &
MICROBIOLOGY
NORTHWESTERN STATE UNIV
NATCHITOCHES, LA 71497
(318) 357-5323

CAMERON, DAVID G
DEPT OF BIOLOGY
MONTANA STATE UNIV
BOZEMAN, MT 59717
(406) 994-2670

CAMPBELL, KENNETH
VCAPP
WASHINGTON STATE UNIV
PULLMAN, WA 99164-6520
(509) 335-6621

CAMPBELL, KEVIN P
DEPT OF PHYSIOL & BIOPHYS
UNIV OF IOWA
IOWA CITY, IA 52240
(319) 351-5833

CHEW, CATHERINE S
DEPT OF PHYSIOLOGY
MOREHOUSE SCHOOL OF
MEDICINE
ATLANTA, GA 30310-1495
(404) 752-1692

CHIEN, DR SHU
DEPT OF PHYSIOL & BIOPHYS
COLUMBIA UNIV
630 WEST 168TH ST
NEW YORK, NY 10032
(212) 305-3686

CHRISTOFFERSON, JAY P
DEPT OF BIOLOGY
CALIFORNIA STATE UNIV AT
STANISLAUS
TURLOCK, CA 95380
(209) 667-3476

CLARK, FRANCIS J
DEPT OF PHYSIOLOGY
UNIV OF NEBRASKA MED CTR
42ND & DEWEY AVE
OMAHA, NE 68105
(402) 559-6478

CLARK, JAMES R
DEPT OF ANIMAL SCIENCE
TEXAS TECH UNIV
PO BOX 4169
LUBBOCK, TX 79409-4169
(806) 742-2469

COCKERHAM, BILL
FRESNO PACIFIC COLLEGE
1717 S CHESTNUT
FRESNO, CA 93702
(209) 453-2045

CONAHAN, SHAWN T
DEPT OF PHYSIOLOGY
LOUISIANA STATE UNIV MED
CENTER
1901 PERDIDO ST
NEW ORLEANS, LA 70112
(504) 582-5783

CONSIGNY, P MACKE
DEPT OF PHYSIOLOGY
MEDICAL COLLEGE OF
PENNSYLVANIA
3300 HENRY AVE
PHILADELPHIA, PA 19129
(215) 842-7059

CUBINA, JOSEFA M
DEPT OF LIFE SCIENCES
NEW YORK INST OF TECH
OLD WESTBURY, NY 11568
(516) 686-7622

CUENA, EUGENIO MARTIN
DPTO DE BIOLOGIA ANIMAL
FACULTAD DE CIENCIAS
UNIVERSIDAD DE GRANADA
GRANADA, SPAIN
202212 EXT 243

DE JONG, ALVIN A
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2209

DICKINSON, PROF C JOHN
DEPT OF MEDICINE
ST BARTHOLOMEW'S HOSP
MEDICAL COLLEGE
WEST SMITHFIELD LONDON,
ENGLAND EC1A7BE

DICKINSON, WINIFRED
DEPT OF BIOLOGY
UNIV OF STEUBENVILLE
STEUBENVILLE, OH 43952
(614) 283-3771

DIGGINS, MAUREEN
DEPT OF BIOLOGY
AUGUSTANA COLLEGE
29TH ST AND S SUMMIT
SIOUX FALLS, SD 57197
(605) 336-4809

DOBSON, ALAN
DEPT OF PHYSIOLOGY
NYS COLLEGE OF VET MED
CORNELL UNIV
ITHACA, NY 14853
(607) 253-3847

DOVE, LEWIS
DEPT OF BIOL SCIENCES
WESTERN ILLINOIS UNIV
MACOMB, IL 61455
(309) 298-1166

DUGGAN, ELEANOR L
BIOLOGY DEPT
UNIV OF N CAROLINA AT
GREENSBORO
ROOM 309, EBERHART BLDG
GREENSBORO, NC 27412-5001
(919) 379-5839

ELDER, DR BETTY
DEPT OF BIOLOGY
GEORGIA SOUTHWESTERN
COLLEGE
AMERICUS, GA 31709
(912) 928-1250

0742-3233/88/$0.00 + 2.00

EUSTIS-TURF, ELIZABETH
BOX 694, MCV STATION
MEDICAL COLLEGE OF
VIRGINIA
RICHMOND, VA 23298
(804) 786-9824

FANNING, MARSHA E
DEPT OF BIOLOGY
LENOIR-RHYNE COLLEGE
HICKORY, NC 28603
(704) 328-7270

FERNER, JOHN W
DEPT OF BIOLOGY
THOMAS MORE COLLEGE
CRESTVIEW HILLS, KY 41017
(606) 344-3374

FREED, DR JAMES M
DEPT OF ZOOLOGY
OHIO WESLEYAN UNIV
DELAWARE, OH 43015
(614) 369-4431 EXT 400

GRAY, F HARRIET
HOLLINS COLLEGE
BOX 9616
HOLLINS COLLEGE, VA 24020
(703) 362-6543

GREEN, JONATHAN
DEPT OF BIOLOGY
ROOSEVELT UNIV
CHICAGO, IL 60605
(312) 341-3676

GOOCH, VAN D
DEPT OF SCIENCE &
MATHEMATICS
UNIV OF MINNESOTA
MORRIS, MN 56267
(612) 589-2211

GRUENER, RAPHAEL
DEPT OF PHYSIOLOGY
UNIV OF MARYLAND AT
BALTIMORE
BALTIMORE, MD 21201
(301) 528-2678

GWINN, DR JOHN F
DEPT OF BIOLOGY
UNIVERSITY OF AKRON
AKRON, OH 44325
(216) 375-7160

HAMPTON, JOHN K
DEPT OF BIOL SCIENCES
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2819

HECKENLIVELY, DONALD B
DEPT OF BIOLOGY
HILLSDALE COLLEGE
HILLSDALE, MI 49242
(517) 437-7341

HEIDCAMP, WILLIAM
DEPT OF BIOLOGY
GUSTAVUS ADOLPHUS
COLLEGE
ST PETER, MN 56082
(507) 931-7325

HEMPLING, HAROLD G
DEPT OF PHYSIOLOGY
MEDICAL UNIV S CAROLINA
CHARLESTON, SC 29425-2658
(803) 792-3648

HILLIARD, STEPHEN
DEPT OF BIOLOGY
BALDWIN-WALLACE COLL
BEREA, OH 44017
(216) 826-2265

HOUSE, EDWIN W
DEPT OF BIOLOGY
IDAHO STATE UNIV
POCATELLO, ID 83209
(208) 236-3765

HOUSE, DR HERBERT W
ELON COLLEGE
BOX 2270
ELON COLLEGE, NC 27244-2010
(919) 584-2294

JEGLA, THOMAS C
DEPT OF BIOLOGY
KENYON COLLEGE
GAMBIER, OH 43022
(614) 427-2244

JENNINGS, MICHAEL L
DEPT OF PHYSIOL & BIOPHYS
UNIV OF IOWA
IOWA CITY, IA 52242
(319) 353-4035

JOHNSON, CLYDE E
DEPT OF BIOL SCIENCES
SOUTHERN UNIVERSITY
BATON ROUGE, LA 70813
(504) 771-5210

JOHNSON, DAVID W
DEPT OF BIOLOGY
CONCORDIA COLLEGE
MOORHEAD, MN 56560
(218) 299-3085

JOHNSON, IVAN M
DEPT OF BIOLOGY
CONCORDIA COLLEGE
MOORHEAD, MN 56560
(218) 299-3085

JOHNSON, WALTER
NORTHWEST COLLEGE OF
CHIROPRACTIC
2501 W 84TH ST
BLOOMINGTON, MN 55431
(612) 888-4777 EXT 290

JONES, MICHAEL E
DEPT OF ANATOMY &
HISTOLOGY
FLINDERS UNIV OF SO
AUSTRALIA
SCHOOL OF MEDICINE
BEDFORD PARK,
SOUTH AUSTRALIA 5042
(618) 275-9911 EXT 4281

JOYNER, RONALD W
DEPT OF PHYSIOLOGY
UNIV OF IOWA
IOWA CITY, IA 52242
(319) 353-7024

KALICHSTEIN, DENNIS
DEPT OF SCIENCE
OCEAN COUNTY COLLEGE
TOMS RIVER, NJ 08753
(201) 255-4000

KENDRICK, J E
DEPT OF PHYSIOLOGY
UNIV OF WISCONSIN
134 SMI
MADISON, WI 53706
(608) 262 1465

KESSLER, SISTER IRMA
DEPT OF BIOLOGY
COLLEGE OF ST ELIZABETH
CONVENT STATION, NJ 07961
(201) 539-1600

LAGLER, REGIS
CRITICAL CARE DEPT
METHODIST HOSPITAL
1701 N SENATE BLVD
INDIANAPOLIS, IN 46202
(317) 929-5293

LAROCHELLE, JACQUES
DEPT OF BIOLOGY
LAVAL UNIV
QUEBEC, PQ
CANADA G1K 7P4
(418) 656-3187

McDONALD, DR GORDON
DEPT OF BIOLOGY
McMASTER UNIV
1280 MAIN ST WEST
HAMILTON, ONTARIO L8S 4K1
CANADA
(416) 525-9140 EXT 4266

McHALE, PHILIP A
DEPT OF PHYSIOL & BIOPHYS
COLLEGE OF MEDICINE,
BMSB-357
UNIV OF OKLAHOMA HEALTH
SCIENCES CENTER
PO BOX 26901
OKLAHOMA CITY, OK 73190
(405) 271-2316

MELNYCHUK, MARK S
DEPT OF BIOL & ALLIED
HEALTH SCIENCE
HART BLOOMSBURG UNIV
SCIENCE CENTER
BLOOMSBURG, PA 17815
(717) 389-4219

MESSICK, JOHN P
DEPT OF BIOLOGY
MISSOURI SOUTHERN STATE
COLLEGE
JOPLIN, MO 64801
(417) 625-9376

MICHAEL, JOEL
DEPT OF PHYSIOLOGY
RUSH MEDICAL COLLEGE
1750 WEST HARRISON ST
CHICAGO, IL 60612
(312) 942-6426

MICKUS, JOHN
DEPT OF BIOLOGY
ILLINOIS BENEDICTINE COLL
LISLE, IL 60532-0900
(312) 960-1500 EXT 509

MIKITEN, TERRY M
GRADUATE SCHOOL OF
BIOMEDICAL SCIENCES
UNIV OF TEXAS
SAN ANTONIO, TX 78284
(512) 567-3709

MILLS, STEVEN H
DEPT OF BIOLOGY
CENTRAL MISSOURI STATE
UNIV
WARRENSBURG, MO 64093
(816) 429-4933

MODELL, HAROLD
DEPT OF RADIOLOGY RC-70
UNIV OF WASHINGTON
SEATTLE, WA 98195
(206) 548-6244

MORIARTY, C MICHAEL
DEPT OF PHYSIOL & BIOPHYS
UNIV OF NEBRASKA MED CTR
OMAHA, NE 68105
(402) 559-7282

OWEN, LAWTON
KANSAS WESLEYAN
SALINA, KS 67401
(913) 827-5541

NOCENTI, DR MR
DEPT OF PHYSIOL & BIOPHYS
COLUMBIA UNIV
NEW YORK, NY 10032
(212) 305-3636

ORTIZ, C LEO
DEPT OF BIOLOGY
UNIV OF CALIFORNIA
SANTA CRUZ, CA 95064
(408) 429-2247

PALMER, KENNETH C
DEPT OF PATHOLOGY
WAYNE STATE UNIV SCHOOL
OF MEDICINE
DETROIT, MI 48201
(313) 577-5152

PARRISH, DR JOHN
DEPT OF BIOLOGY
EMPORIA STATE UNIV
EMPORIA, KS 66801
(316) 343-1200

PETERSON, NILS
DEPT OF COMPUTER &
INFORMATION SCIENCE
UNIV OF OREGON
EUGENE, OR 97403-1201
(503) 686-3989

QUINN, DAVID L
DEPT OF BIOLOGY
MUSKINGUM COLLEGE
NEW CONCORD, OH 43762-1199
(614) 826-8225

RAM, JEFFREY L
DEPT OF PHYSIOLOGY
WAYNE STATE UNIV SCHOOL
OF MEDICINE
DETROIT, MI 48201
(313) 577-1558

REINKING, LARRY N
DEPT OF BIOLOGY
MILLERSVILLE UNIV
MILLERSVILLE, PA 17551
(717) 872-3792

RIESEN, JOHN
DEPT OF ANIMAL SCIENCE
UNIV OF CONNECTICUT U-40
STORRS, CT 06268
(203) 486-2541

ROBBINS, DR HERBERT C
DALLAS BAPTIST UNIV
7777 WEST KIEST BLVD
DALLAS, TX 75211-9800
(214) 333-5302

ROE, WALTER E
DEPT OF VET PHYSIOL SCI
UNIV OF SASKATCHEWAN
SASKATOON, SK S7N 0W0
CANADA
(306) 966-7371

ROSELLI, ROBERT J
DEPT OF CHEM ENGINEERING
VANDERBILT UNIV
BOX 36 STATION B
NASHVILLE, TN 37235
(615) 322-2602

ROTHE, DR CARL F
DEPT OF PHYSIOL & BIOPHYS
INDIANA UNIV SCHOOL OF
MEDICINE
635 BARNHILL DRIVE
INDIANAPOLIS, IN 46223
(317) 264-8250

ROVICK, ALLEN A
DEPT OF PHYSIOLOGY
RUSH MEDICAL COLLEGE
CHICAGO, IL 60612
(312) 942-6567

RUF, DR KURT B
DEPT OF PHYSIOL & BIOPHYS
DALHOUSIE UNIV
HALIFAX, NOVA SCOTIA
CANADA B3H 4H7
(902) 424-3517

SAGE, MARTIN
DEPT OF BIOLOGY
UNIV OF MISSOURI AT
ST LOUIS
8001 NATURAL BRIDGE RD
ST LOUIS, MO 63121
(314) 553-6218

SCHMIDT, THOMAS J
DEPT OF PHYSIOL & BIOPHYS
UNIV OF IOWA
IOWA CITY, IA 52242
(319) 353-4018

SCHNEIWEISS, JEANNETTE W
DEPT OF BIOLOGY
HOFSTRA UNIV
HEMPSTEAD, NY 11550
(516) 560-5521

SIEGMAN, MARION
DEPT OF PHYSIOLOGY
JEFFERSON MEDICAL COLL
1020 LOCUST ST
PHILADELPHIA, PA 19107
(215) 928-7893

SIMPSON, R J
DEPT OF BIOLOGY
UNIV OF NORTHERN IOWA
CEDAR FALLS, IA 50614
(319) 273-2645

SINNAMON, WALT
CENTRAL WESLEYAN COLL
CENTRAL, SC 29630
(803) 639-2453 EXT 356

SLAYMAN, C L
DEPT OF PHYSIOLOGY
YALE SCHOOL OF MEDICINE
NEW HAVEN, CT 06510-8026
(203) 788-4478

SMALL, JAMES W
DEPT OF BIOLOGY
ROLLINS COLLEGE
WINTER PARK, FL 32789
(305) 646-2433

STEIN, PAUL
DEPT OF BIOLOGY
WASHINGTON UNIV
ST LOUIS, MO 63130
(314) 889-6824

STENROOS, ORRIE O
DEPT OF BIOLOGY
LYNCHBURG COLLEGE
1501 LAKESIDE DR
LYNCHBURG, VA 24501
(804) 522-8362

STOUT, JOHN
DEPT OF BIOLOGY
ANDREWS UNIV
BERRIEN SPRINGS, MI 49104
(616) 471-3243

SULAKHE, DR P V
DEPT OF PHYSIOLOGY
COLLEGE OF MEDICINE
UNIV OF SASKATCHEWAN
SASKATOON, SK S7N 0W0
CANADA
(306) 966-6534

SWEET, HAVEN
DEPT OF BIOLOGY
UNIV OF CENTRAL FLORIDA
ORLANDO, FL 32816
(305) 275-2922

TAYLOR, JAMES WM
KALAMAZOO VALLEY
COMMUNITY COLLEGE
KALAMAZOO, MI 49009
(616) 372-5356

TESKEY, SISTER NANCY
HOLY NAMES COLLEGE
OAKLAND, CA 94619
(415) 436-0111

THIRUMALAI, CHARLES HR
DEPT OF PHYSIOLOGY
UNIV WEST INDIES
KINGSTON 7, JAMAICA
WEST INDIES
(809) 927-2090

TURNELL, M J
DEPT OF ZOOLOGY
UNIVERSITY OF ALBERTA
CW 312 BIOL SCI BLDG
EDMONTON, ALBERTA
CANADA T6G 2E9
(403) 432-0665

VAN AMBURG, GERALD L
DEPT OF BIOLOGY
CONCORDIA COLLEGE
MOORHEAD, MN 56560
(218) 299-3085

WALKER, RICHARD
STERLING COLLEGE
STERLING, KS 67579
(316) 278-2173

WATROUS, JAMES
DEPT OF BIOLOGY
ST JOSEPH'S UNIV
PHILADELPHIA, PA 19131
(215) 879-7342

WEISBART, DR MELVIN
DEPT OF BIOLOGY
ST FRANCIS XAVIER UNIV
ANTIGONISH, NOVA SCOTIA
CANADA B2G 1C0
(902) 867-2294

WILHELM, DALLAS
DEPT OF BIOLOGY
HASTINGS COLLEGE
HASTINGS, NE 68901
(402) 463-2402 EXT 264

WILLIAMS, W E
DEPT OF BIOLOGY
TRINITY COLLEGE
HARTFORD, CT 06106
(203) 527-3151 EXT 570

WILLISTON, JOHN S
DEPT OF BIOLOGY
SAN FRANCISCO STATE UNIV
SAN FRANCISCO, CA 94132
(415) 584-5319

WILSON, DR MARLENE M
UNIV OF PORTLAND
PORTLAND, OR 97203
(503) 283-7123

WOLF, MATTHEW B
DEPT OF PHYSIOLOGY
SCHOOL OF MEDICINE
UNIV S CAROLINA
COLUMBIA, SC 29208
(803) 733-3241

WOLLIN, A
DEPT OF PHYSIOLOGY
COLLEGE OF MEDICINE
UNIV OF SASKATCHEWAN
SASKATOON, SK 57N 0W0
CANADA

WUNDER, CHARLES C
PHYSIOLOGY RESEARCH LAB
UNIV OF IOWA
OAKDALE, IA 52319
(319) 353-4704

YORK, DR DONALD H
DEPT OF PHYSIOLOGY
UNIV OF MISSOURI AT
COLUMBIA
COLUMBIA, MO 65212
(314) 882-7168

YOUNG, BRUCE A
DEPT OF ANIMAL SCIENCE
UNIVERSITY OF ALBERTA
EDMONTON, ALBERTA
CANADA T6G 2P5
(403) 432-3233

ZEITTER, SHIRLEY
DAVENPORT COLLEGE
415 EAST FULTON
GRAND RAPIDS, MI 49503
(616) 451-3511

ZIMMERMAN, JAY
DEPT OF BIOL SCIENCES
ST JOHN'S UNIV
GRAND CENTRAL &
UTOPIA PKWS
NEW YORK, NY 11439
(718) 990-6161 EXT 5233

PLANT PHYSIOLOGY

STEUCEK, DR GUY L
DEPT OF BIOLOGY
MILLERSVILLE UNIV
MILLERSVILLE, PA 17551
(717) 872-3339

PSYCHIATRY

PARISI, ANTHONY J
WRIGHT STATE UNIV SCHOOL
OF MEDICINE
DAYTON, OH 45401-0927
(513) 376-6711

RESEARCH TECHNIQUES

GLYNIS, ASU
MCW LIBRARIES
8701 WATERTOWN PLANK RD
MILWAUKEE, WI 53226
(414) 257-8323

MESSICK, JOHN P
DEPT OF BIOLOGY
MISSOURI SOUTHERN STATE
COLLEGE
JOPLIN, MO 64801
(417) 625-9376

SEROLOGY

STANSFIELD, WILLIAM
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2875

STATISTICS

BENEDICT, DR SUSAN
209 MOUNTAIN RIDGE DRIVE
HUNTSVILLE, AL 35801
(205) 536-7101

BROOKE, DR JOHN D
NEUROPHYSIOLOGY LAB
UNIVERSITY OF GUELPH
SCHOOL OF HUMAN BIOLOGY
GUELPH, ONTARIO N1G 2W1
CANADA
(519) 824-4120 EXT 3416

CHEW, F S
DEPT OF BIOLOGY
TUFTS UNIV
MEDFORD, MA 02155
(617) 381-3189 EXT 3195

CLARK, JAMES R
DEPT OF ANIMAL SCIENCE
TEXAS TECH UNIV
LUBBOCK, TX 79409-4169
(806) 742-2469

CODY, RONALD
DEPT OF ENVIRON &
COMMUNITY MEDICINE
RUTGERS MEDICAL SCHOOL
PISCATAWAY, NJ 08854
(201) 463-4490

FASHING, NORMAN J
DEPT OF BIOLOGY
COLLEGE OF WILLIAM
AND MARY
WILLIAMSBURG, VA 23185

HAGEN, STANLEY VON
DEPT OF PHARMACOLOGY
NEW JERSEY MEDICAL SCH
NEWARK, NEW JERSEY 07103
(201) 456-4385

RIPPEY, ROBERT
RHE AMO34
UNIV CONN HLTH CTR
FARMINGTON, CT 06073
(203) 674-2353

0742-3233/88/$0.00 + 2.00

SCHWARTZ, ORLANDO A
DEPT OF BIOLOGY
UNIV OF NORTHERN IOWA
CEDAR FALLS, IA 50614
(319) 273-2106

TAUB, STEPHAN R
DEPT OF BIOLOGY
GEORGE MASON UNIV
FAIRFAX, VA 22030
(703) 323-2181

WERNER, J KIRWIN
DEPT OF BIOLOGY
NORTHERN MICHIGAN UNIV
MARQUETTE, MI 49855
(906) 227-2310

TAXONOMY

WALTERS, DIRK R
DEPT OF BIOLOGY
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93406
(805) 546-2721

VIROLOGY

BOND, CLIFFORD
DEPT OF MICROBIOLOGY
MONTANA STATE UNIV
BOZEMAN, MT 59717
(406) 994-4130

ZOOLOGY

BLACK, JOE B
DEPT OF BIOLOGY
LOUISIANA COLLEGE
LOUISIANA COLLEGE STA
PINEVILLE, LA 71359
(318) 487-7611

BUCHHOLZ, ROBERT H
DEPT OF BIOLOGY
MONMOUTH COLLEGE
MONMOUTH, IL 61462
(309) 457-2350

CARICO, JAMES E
DEPT OF BIOLOGY
LYNCHBURG COLLEGE
LYNCHBURG, VA 24501
(804) 522-8366

COCKERHAM, BILL
FRESNO PACIFIC COLLEGE
1717 S CHESTNUT
FRESNO, CA 93702
(209) 453-2045

DE JONG, ALVIN A
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2209

DICKINSON, WINIFRED
DEPT OF BIOLOGY
UNIV OF STEUBENVILLE
STEUBENVILLE, OH 43952
(614) 283-3771

DIGGINS, MAUREEN
DEPT OF BIOLOGY
AUGUSTANA COLLEGE
29TH ST AND S SUMMIT
SIOUX FALLS, SD 57197
(605) 336-4809

GAMBS, ROGER
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2551

GIBSON, LINDA
DEPT OF BIOLOGY
EASTERN WASHINGTON UNIV
CHENEY, WA 99004
(509) 359-2845

GRAY, F HARRIET
HOLLINS COLLEGE, BOX 9616
HOLLINS COLLEGE, VA 24020
(703) 362-6543

HILTON, DONALD FJ
DEPT OF BIOL SCIENCES
BISHOP'S UNIVERSITY
LENNOXVILLE, QUEBEC
CANADA J1M 1Z7
(819) 569-9551

LEONG, KINGSTON
DEPT OF BIOL SCIENCE
CAL POLYTECH STATE UNIV
SAN LUIS OBISPO, CA 93407
(805) 546-2788

MACHIN, DR JOHN
DEPT OF ZOOLOGY
UNIV OF TORONTO
TORONTO, ONTARIO
CANADA M5S 1A1
(416) 978-3506

MURPHY, GEORGE
MIDDLE TENN STATE UNIV
MURFREESBORO, TN 37132
(615) 898-2847

OWEN, LAWTON
KANSAS WESLEYAN
SALINA, KS 67401
(913) 827-5541

SINGLETARY, ROBERT L
DEPT OF BIOLOGY
UNIV OF BRIDGEPORT
BRIDGEPORT, CT 06601
(203) 576-4265

SINNAMON, WALT
CENTRAL WESLEYAN COLL
BOX 443
CENTRAL, SC 29630
(803) 639-2453 EXT 356

STANTON, GEORGE E
DEPT OF BIOLOGY
COLUMBUS COLLEGE
COLUMBUS, GA 31993
(404) 568-2065

STEVENS, E D
DEPT OF ZOOLOGY
UNIV OF GUELPH
GUELPH, ONTARIO
CANADA N1G 2W1
(519) 824-4120 EXT 2137

SUBSCRIPTION INFORMATION

Computers in Life Science Education is published monthly by National Resource for Computers in Life Science Education, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Subscription rate is $30.00 for 12 issues, including postage and handling in the United States and Canada. Add $20.00 for postage (airmail) in Mexico and Europe and $23.00 for the rest of the world.

This newsletter has been registered with the Copyright Clearance Center, Inc. Consent is given for copying of articles for personal or internal use, or for the personal or internal use of specific clients. This consent is given on the condition that the copier pay through the Center the per-copy fee stated in the code on the first page for copying beyond that permitted by the US Copyright Law. If no code appears on an article, the author has not given broad consent to copy and permission to copy must be obtained directly from the author. This consent does not extend to other kinds of copying, such as for general distribution, resale, advertising and promotional purposes, or for creating new collective works.

Address orders, changes of address, and claims for missing issues to NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Claims for missing issues can be honored only up to three months for domestic addresses and six months for foreign addresses. Duplicate copies will not be sent to replace ones undelivered due to failure to notify NRCLSE of change of address.

Address editorial correspondence to Harold I. Modell, PhD, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. (BITNET MODELL@UWALOCKE)

POSTMASTER: Send address changes to *Computers in Life Science Education*, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

0742-3233/88/$0.00 + 2.00

VOLUME 5 NUMBER 5, MAY 1988

CLSEE3 5(5)33-40, 1988 ISSN 0742-3233

COMPUTERS IN LIFE SCIENCE EDUCATION

HAROLD I. MODELL
Department of Radiology
University of Washington
Seattle, Washington

MARCEL BLANCHAER
Department of Biochemistry
Faculty of Medicine
University of Manitoba
Winnipeg, Manitoba

THEODORE J. CROVELLO
Graduate Studies and Research
California State University, Los Angeles
Los Angeles, California

JAMES W. ECKBLAD
Department of Biology
Luther College
Decorah, Iowa

TSEGAYE HABTEMARIAM
School of Veterinary Medicine
Tuskegee University
Tuskegee, Alabama

DONNA LARSON
School of Nursing
Grand Valley State College
Allendale, Michigan

TERRY M. MIKITEN
Graduate School of Biomedical Sciences
University of Texas Health Science Center
San Antonio, Texas

JAMES E. RANDALL
Department of Physiology
Indiana University
Bloomington, Indiana

PATRICIA SCHWIRIAN
College of Nursing
Ohio State University
Columbus, Ohio

RICHARD STULL
College of Pharmacy
University of Arkansas
Little Rock, Arkansas

JAMES W. WOODS
Lister Hill National Center
for Biomedical Communications
National Library of Medicine
Bethesda, Maryland

DOROTHY WOOLEY-McKAY
Department of Biology
Glendale Community College
Glendale, Arizona

GLEN YOSHIDA
Department of Life Sciences
Los Angeles Southwest College
Los Angeles, California

NRCLSE

CONTENTS

HYPERCARD — WHAT IS IT? 33
Dorothy Wooley-McKay

WHERE'S THE SOFTWARE? 35

HYPERCARD — WHAT IS IT?

Dorothy Wooley-McKay
Department of Biology, Glendale Community College, Glendale, Arizona

Many individuals familiar with the Apple Macintosh microcomputer are talking about what some believe is a revolutionary new product. The product is called HyperCard, and it was released by Apple Computer at the MacWorld Expo in Boston in August, 1987.

WHAT IS HYPERCARD?

This is a difficult question to answer because it is many things to different people. The author of HyperCard, Bill Atkinson (also author of MacPaint), has called HyperCard a "software erector set". Presumably, it is a means by which individuals who have never programmed a computer can now do so. However, HyperCard is more than that.

HyperCard is based on the concept of hypertext. Hypertext is a system of transferring information by means of a computer rather than books or other print media. Some, of course, will not like this manner of information transfer. However, it has some advantages.

What does HyperCard have to do with using computers in the life sciences? Consider the following situation. A student is studying the electrical activity of the heart. In order to understand the principles, he must be familiar with electrophysiology, including the concepts of depolarization and repolarization. Of course, the student has a textbook and lecture notes to use as reference material. However, the sections on electrophysiology were covered in the previous semester, and the student has forgotten much of what was learned in those sections. He must go back and review that material. Unfortunately, the student cannot find the lecture notes from the previous semester. There is still the textbook, but this student never opened the textbook. He

0742-3233/88/$0.00 + 2.00

used only lecture notes to study because the exams were based on the lecture notes, and he doesn't know where to find the textbook on electrophysiology. This, of course, is an extreme case. However, using HyperCard or another form of hypertext, we can create the following scenario.

This same student is studying the electrical activity of the heart using HyperCard stacks. HyperCard software consists of stacks. The analogy is a stack of cards. Each stack is divided into cards that are accessed one at a time. On each card, there are fields for text, graphics and buttons (see Figure 1). Part of the heart stack is a tutorial including text (read from the computer monitor) and graphics. When the student gets stuck with the electrophysiological concepts, he clicks (with the mouse) on a button located on one of the cards of the heart stack. When he clicks on this particular button, he is immediately shown a stack on basic electrophysiology. In this stack there may be a simulation of an action potential in a nerve fiber as well as text and graphics explaining the principles of electrophysiology. When the student has finished with electrophysiology, he clicks on another button and goes back to the heart. The same process could be used to connect the anatomy of the heart with the physiology of the heart. For example, when studying the Purkinje system, the student could click on Purkinje system and go to a card illustrating the location of this system. All of the information is linked together in an intuitive way. Instead of information being presented in a serial form, it can be linked together in a way more logical to human thought.

EXAMPLE APPLICATIONS

The following applications for teaching life sciences using HyperCard were described in the March 29th issue of MacWeek magazine.

- **Interactive Medical Record** This was developed by Dr. Edward Shultz at Dartmouth Medical School. Using this stack, a student can, among other things, point to a patient's chest and hear the digitized sound of a heart murmur. In addition, the students can click on buttons to see vital signs, X-Rays, past visits, and blood smears. There is also a glossary, so students can click on any word and look it up in the glossary.

- **Electric Cadaver** This application, developed by Drs. Robert Chase and Steven Freedman of Stanford University Medical School presents anatomical drawings on the monochrome monitor of a Mac II. When a student clicks on a part of the image, that portion is presented on the screen. In addition, color photographs of those structures are shown on a video monitor. The color photographs are taken from the Basset series of 3 dimensional anatomical drawings.

(HyperCard can access videodiscs that contain color photographs of almost anything. The student can thus move easily from a large view of an anatomical structure to more detailed aspects of the same structure.)

- **MAClinical** This is a project at Georgetown University Medical School. At the present time, there are two HyperCard stacks being used, HypeRite Up and a stack teaching the anatomy of the hand.

The spectrum of possibilities using HyperCard in education is almost limitless. There is the ability to incorporate digitized sound, such as heart murmurs (realistic sounds, not computer sounds) into HyperCard stacks. HyperCard stacks can be linked to videodiscs. HyperCard stacks can also be linked to real time animations using VideoWorks. Students can easily jump from one subject to a related subject. HyperCard stacks can be made as tutorials, simulations or addenda to laboratory exercises. Eventually, a large data base of any kind of information can be stored on CD ROM players and accessed with HyperCard.

If I wax eloquent on the possibilities of using HyperCard in education, it is because I think the potential of HyperCard has barely been tapped.

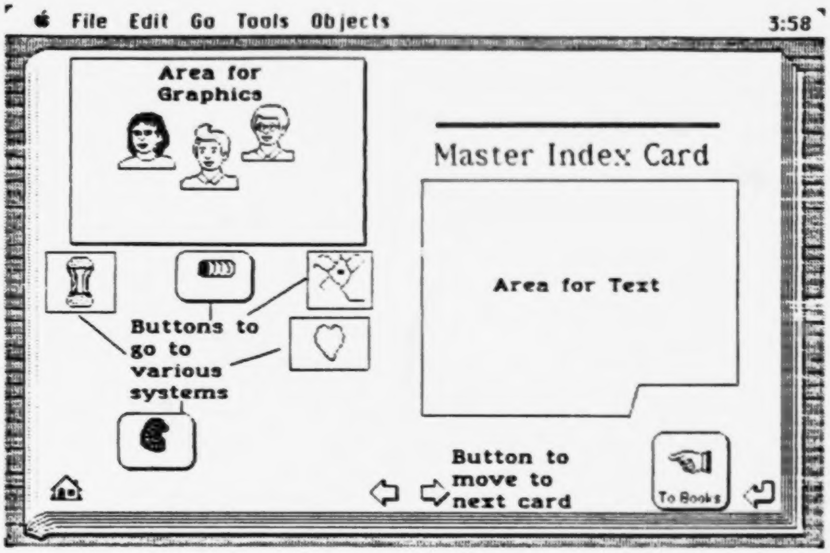


FIGURE 1. Example of fields available on HyperCard cards.

WHERE'S THE SOFTWARE?

In the past, we have published lists of life science software sources and programs available through them. The following list is presented as the latest in a continuing effort to make colleagues aware of potential resources. As in the past, no attempt has been made by NRCLSE to review these materials.

This month's listings are arranged by content area. Each item includes a vendor code relating the software to the vendors list appearing on page 39.

If you have found specific software helpful in your teaching efforts, please share your good fortune by letting us know about the program(s) and supplier(s) so that we can make this information available through future software lists. Send pertinent information to Dr. Harold Modell, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195 or send us a note on BITnet. Our BITnet address is MODELL@UWALOCKE.

ANATOMY

GROSS ANATOMY TUTORIAL

Tutorial for gross anatomy review by region and for self-test in National Board format. Program available for Apple II equipment. L.1

HEART LAB

Animated graphics simulation of human heart. Program available for Apple II, TRS-80 Models I and III, PET, and Atari 800/800XL equipment. E.1

HUMAN ANATOMY PICTURE FILE

Hi-Res diagrams of heart, brain, eye, ear, respiratory system, kidney, endocrine system, neurons, circulatory system schematic, and digestive system. Program available for Apple II equipment. D.1

LOCOMOTION

Tutorial reviewing types and functions of bones and muscles. Program available for Apple II and TRS-80 Model III equipment. J.1

BIOCHEMISTRY

ANIMATIONS

Contains animations for demonstrating DNA structure and synthesis, RNA structure and synthesis, and protein synthesis. Program available for Apple II equipment. E.3

BIOCHEMISTRY

Tutorial covering basic atomic structure, balancing equations, and properties of proteins and carbohydrates. Program available for Apple II and TRS-80 Model III equipment. J.1

DNA STRUCTURE AND SYNTHESIS

Tutorial dealing with nucleotide structure and linkage between nucleotide, base complementarity and hydrogen bonding. Program available for Apple II equipment. E.3

ENZKIN: Enzyme Kinetics

Simulation of enzyme-catalyzed reactions. Program available for Apple II equipment. C.4

ENZLAB

Simulations for designing and carrying out enzyme kinetics experiments. Program available for Apple II and IBM-PC compatible equipment. B.1

ENZPACK

An enzyme kinetics teaching and calculation program. Program available for Apple II and IBM-PC compatible equipment. B.1

ENZYME ACTION

Tutorial on the basic nature and function of enzymes. Program available for Apple II equipment. B.1

ENZYME-SIMULATION, ENZYME ACTION

Simulation of enzyme action and the effects of inhibitors using acetylcholinesterase. Program available for Apple II, TRS-80 Models I and III, IBM-PC, and Commodore 64/128 equipment. D.2

GENE MACHINE

Tutorial/Simulation dealing with DNA replication and protein synthesis. Program available for Apple II equipment. H.1

MOLECULAR BIOLOGY SERIES

Programs demonstrating central processes of RNA and protein synthesis and DNA synthesis and repair. Program available for Apple II and IBM-PC compatible equipment. B.1

MOLGRAF

Molecular graphics package. Program available for Apple II and IBM-PC compatible equipment. B.1

THE NUCLEIC ACIDS

Tutorial/Simulation dealing with principal nucleotides and synthesis of RNA. Program available for Apple II equipment. E.2

PROTEIN SYNTHESIS

Tutorial dealing with the general structure of the amino acids and formation of peptide bonds. Program available for Apple II equipment. E.3

RNA STRUCTURE AND SYNTHESIS

Tutorial extending the concept of hydrogen bonding between complementary bases to show the synthesis of RNA on the DNA template and the analogies in structure between DNA and RNA. Program available for Apple II equipment. E.3

BIOLOGY

ADAPTION AND IDENTIFICATION

Tutorial covering animal adaptation to different environments and animal identification. Program available for Apple II equipment. S.1

ANIMAL REPRODUCTION

Tutorial reviewing sperm development, egg and fertilized egg. Program available for Apple II and TRS-80 Model III equipment. J.1

ASEXUAL REPRODUCTION

Tutorial reviewing cell division. Program available for Apple II and TRS-80 Model III equipment. J.1

BIOLOGY COMPUTER STIMULATIONS

Tutorial covering various biological concepts and experimental areas including enzymes, photosynthesis, respiration, diffusion, meiosis, muscles, nerves, and genetics. Program available for Apple II and TRS-80 Models I and III equipment. L.1

DIFFUSION AND ACTIVE TRANSPORT

Tutorial covering diffusion, osmosis, and active transport in biological systems. Program available for Apple II equipment. S.2

ENERGETICS AND METABOLISM, GARDEN OF BIOLOGY: VOLUME I

Data base illustrating reactions of metabolism and interactions between the several metabolic compartments of a cell. Program available for Macintosh equipment. K.1

EVOLUTION, GARDEN OF BIOLOGY: VOLUME 2

Data base illustrating relations among organisms of many kinds, emphasizing the history and mechanics of their evolutionary change. Program available for Macintosh equipment. K.1

KNOWLEDGE MASTER - BIOLOGY 2

Test-item database for test generation. Content covers coelenterates, arthropods, insects, fish, amphibians, and reptiles. Part of a 5-program Biology series for Apple II equipment. A.1

KNOWLEDGE MASTER - BIOLOGY 3

Test-item database for test generation. Content covers birds, mammals, primates, protists, bacteria and taxonomic zoology. Part of a 5-program Biology series for Apple II equipment. A.1

OSMO- OSMOSIS IN RED BLOOD CELLS

Simulation of red blood cells in hypertonic, hypotonic, and isotonic solutions. Program available for Apple II, TRS-80 Model III, IBM-PC, and Commodore 64/128 equipment. D.2

OSMOSIS AND DIFFUSION

Tutorial/Simulation covering effects of temperature, concentration, solubility, molecule size and charge, and membrane pore size on flow of matter across semi-permeable membranes. Program available for Apple II, TRS-80 Models I and III equipment. E.2

OSMOTIC PRESSURE

Simulation of thistle tube experiments and animation of a molecular model for osmosis. Program available for Apple II equipment. C.4

PASSIVE TRANSPORT

Tutorial-simulation covering diffusion and osmosis. Program for MS-DOS compatible equipment. C.1

SIMULATION OF HEMOGLOBIN FUNCTION

Simulations of hemoglobin and myoglobin functions. Program for Apple II equipment. C.2

BOTANY

ALGAL GROWTH

Simulation of the effects of eight variables on growth of algae. Program available for Apple II and IBM-PC compatible equipment. O.1

BIOLOGY FRUIT KEY

Identifies 125 trees and shrubs. Program available for Atari 400/800 equipment. D.3

COMPETE:Plant competition

Simulation of experiments involving interaction between flowering plants. Program available for Apple II equipment. C.4

FAMILY IDENTIFICATION

Data retrieval program to review the characteristics of 74 North American flowering plant families. Program available for Apple II equipment. C.4

LEAF: STRUCTURE AND FUNCTION

Tutorial-simulation covering the anatomy and physiology of the leaf with respect to its role as the "chemical factory" of the plant. Program for IBM-PC (PC-DOS). C.1

PHOTOSYNTHESIS AND LIGHT ENERGY

Simulation focuses on characteristics of light and its role as an energy source. Program for IBM-PC (PC-DOS). C.1

PHOTOSYNTHESIS AND RESPIRATION

Demonstration and simulations focusing with light and dark reactions of photosynthesis, respiration, and ATP cycle. Program available for Apple II equipment. S.1

PHOTOSYNTHESIS & TRANSPORT

Tutorial dealing with photosynthesis and transport in plants. Program available for Apple II and TRS-80 Model III equipment. J.1

PLANT ANATOMY PICTURE FILE

Hi-Res diagrams of roots, stem cross-section, leaf cross-section, photosynthesis, flowers, seeds, and germination. Program available for Apple II equipment. D.1

PLANT GROWTH

Tutorial-simulation covering physiology of growth beginning with the seed. Covers hormone control, feedback mechanisms, transport, and differentiation. Program for IBM-PC (PC-DOS). C.1

PLANT-PLANT GROWTH SIMULATION

Simulation of the effects of light intensity and duration on growth and development of green plants. Program available for Apple II, TRS-80 Models I and III, IBM-PC, and Commodore 64/128 equipment. D.2

REPRODUCTION IN PLANTS

Tutorial reviewing asexual and sexual reproduction in plants. Program available for Apple II and TRS-80 Model III equipment. J.1

SOLAR FOOD

Tutorial/Simulation dealing with photosynthesis. Program available for Apple II equipment. H.1

CYTOLOGY

CELL CHEMISTRY I

Tutorial covering various chemical structures. Program available for Apple II and IBM-PC compatible equipment. S.3

CELL CHEMISTRY II

Tutorial covering the chemical and physical processes that occur within cells. Program available for Apple II and IBM-PC compatible equipment. S.3

CELLGROW

Simulation of cell kinetics. Program available for Apple II equipment. U.1

CELL GROWTH AND MITOSIS

Interactive simulation covering surface area-volume ratio, chromosome number, chromosome replication, and cytoplasmic division. Program for IBM-PC (PC-DOS). C.1

CELLS: STRUCTURE AND FUNCTION

Simulation reinforces basic concepts of cell structure, cell functions, water movement and concentration gradients, and diffusion and active transport. Program available for Apple II equipment. S.1

ECOLOGY

AIR POLLUTION

Simulation of carbon monoxide pollution in an urban environment. Program available for Apple II and TRS-80 Model I and III equipment. E.2

AQUATIC ECOLOGY

Utilities to perform many of the calculations common to aquatic ecology. Program available for Apple II and IBM-PC equipment. O.1

AQUATIC ECOLOGY DATA SIMULATION

25 simulations covering aquatic systems. Program available for Apple II and IBM-PC equipment. O.1

ECOLOGICAL DATA SIMULATION

25 simulations covering ecological systems. Program available for Apple II and IBM-PC equipment. O.1

ECOLOGY

Rote drill reviews and reinforces concepts of general terrestrial, and aquatic ecology. Available for Apple II and IBM-PC compatible equipment. S.3

ECOLOGY

Simulation dealing with plant population sizes and growth pattern. Available for Apple II equipment. S.1

ECOLOGICAL ANALYSIS - PC

Utilities that perform life table analysis, interspecific association indices, community similarity, diversity indices, descriptive statistics, mark-release recapture analysis, plus regression and correlation analysis. Program available for IBM-PC compatible equipment. O.1

ECOLOGICAL ANALYSIS VOL. 2 - PC

Utilities that perform community similarity analysis, indices of dispersion, species-area curve, and step-wise multiple regression. Program available for IBM-PC compatible equipment. O.1

ECOLOGICAL ANALYSIS PROGRAMS PLUS

Utilities that perform life table analysis, community similarity indices, diversity indices, predator-prey modeling, mark-recapture analysis, descriptive statistics, plus regression and correlation analysis. Program available for Apple II equipment. O.1

ECOLOGICAL MODELING

Series of 7 programs dealing with a variety of techniques for modeling ecological systems and processes. Program available for Apple II and IBM-PC compatible equipment. C.4

NICHE-ECOLOGICAL GAME/ SIMULATION

Game in which students attempt to place an organism in its proper ecological niche correctly by specifying environment, range, and competitor. Program available for Apple II, TRS-80 Models I and III, IBM-PC, and Commodore 64/128 equipment. D.2

POLLUTE

Simulation of factors affecting water quality. Includes temperature, amount and type of pollutant, and water treatment. Program available for Apple II, PET/CBM, and TRS-80 Model III equipment. C.3

POLLUTE:IMPACT/WATER POLLUTANTS

Simulation of the impact of various pollutants on typical bodies of water. Program available for Apple II, TRS-80 Models I and III, IBM-PC, and Commodore 64/128 equipment. D.2

WATER POLLUTION

Simulation of the effects of temperature, type of waste, dumping rate, and method of treatment on the impact of pollution on aquatic life. Program available for Apple II, TRS-80 Models I and III equipment. E.2

EVOLUTION

EVOLUT: Evolution and Natural Selection

Simulation of fluctuations in gene frequenceis of wild populations. Program available for Apple II equipment. C.4

EVOLUTION

Simulations covering mutation, gene flow, natural selection, and genetic drift on populations. Program available for Apple II and IBM-PC compatible equipment. O.1

GENETICS

ADVANCED GENETICS

Tutorial/Simulation presented as a nine-part program covering dominance and recessiveness, partial dominance, lethality, mechanism of inheritance, multiple alleles, sex linkage, multi-trait inheritance, crossing over, and gene mapping. Program available for Apple II equipment. E.2

CATGEN

Simulation allowing students to mate domestic cats of known genotypes. Program available for Apple II and IBM-PC compatible equipment. C.4

CATLAB (Second Edition)

Simulation in introductory genetics. Program available for Apple II and IBM-PC compatible equipment. C.4

CELLS AND GENETICS PICTURE FILE

Hi-Res diagrams of animal cell, plant cell, mitosis, meiosis, Punnett Square, sex linked traits, DNA replication, protozoa, energy reactions, and pedigree. Program available for Apple II equipment. D.1

DICROSS-DIHYBRID CROSSES

Simulation of various types of dihybrid crosses. Program available for Apple II, TRS-80 Models I and III, IBM-PC, and Commodore 64/128 equipment. D.2

DNA-THE MASTER MOLECULE

Simulation dealing with DNA structure. Programs available for Apple II equipment. E.2

DNAGEN-DNA/GENETIC CODE SIMULATION

Simulation of genetic code to produce protein sequences. Program available for Apple II, TRS-80 Models I and III, IBM-PC, and Commodore 64/128 equipment. D.2

FLYGEN

Simulation of monohybrid or dihybrid crosses with 25 varieties of Drosophila. Program available for Apple II, TRS-80 Models I and III, IBM-PC, and Commodore 64/128 equipment. D.2

GENESIM

Simulations of experminents in bacterial and molecular genetics. Program available for Apple II and IBM-PC compatible equipment. B.1

GENTIC DRIFT

Tutorial-simulation focusing on random changes with time in the distribution of individuals in small populations. Program for Apple II equipment. C.2

GENETICS

Tutorial covering various crosses in plants and fruit fly populations. Program available for Apple II and TRS-80 Model III and IV equipment. J.1

GENETICS

Tutorial that allows students to explore Mendel's experiments, Punnett Squares, sex linkage in fruit flies, and multiple alleles. Program available for Apple II equipment. S.1

GENETICS

Tutorial examines DNA molecule and progresses to applied genetics. Program available for Apple II and IBM-PC compatible equipment. S.3

HEREDITY DOG

Tutorial covering various genetic topics. Program available for Apple II and Commodore 64/128 equipment. H.1

HUMAN GENETIC DISORDERS

Simulation investigating inherited disorders. Program available for Apple II equipment. H.1

INTRODUCTORY GENETICS

Three part tutorial covering a variety of topics. Program available for Apple II, TRS-80 Models I and III equipment. E.2

LIFE

Educational game dealing with changing distributions of individuals. Program for Apple II equipment. C.2

LINKOVER: Genetic Mapping

Simulation of genetic mapping experiments. Program available for Apple II equipment. C.4

MEIOSIS

Tutorial/Simulation providing an interactive portrayal of gamete formation. Program available for Apple II and IBM-PC equipment. E.2

MEIOSIS, MITOSIS, PROTEIN SYNTHESIS

Simulation demonstrating mitosis, meiosis, DNA replication, and protein synthesis. Program available for Apple II equipment. S.1

MENDELIAN GENETICS

Simulation covering dominance, partial dominance, lethatlity, linkage, and sex linkage. Program for Apple II equipment. C.2

MONOCROS-MONOHYBRID CROSSES

Simulation of various monohybrid genetic crosses. Program available for Apple II, TRS-80 models I and III, IBM-PC, and Commodore 64/128 equipment. D.2

NATURAL SELECTION

Tutorial/Simulation dealing with genetics and evolution to populations. Program available for Apple II equipment. E.2

POPGEN-POPULATION GENETICS

Simulation of the effects of Hardy-Weinberg Law conditions on gene, genotype, and phenotype frequencies of a population over time. Program available for Apple II, TRS-80 Models I and III, IBM-PC, and Commodore 64/128 equipment. D.2

MICROBIOLOGY

DILUTE-MICROBIAL DILUTION SERIES

Simulation covering design and testing of microbial dilution series to determine concentration of a bacterial solution. Program available for Apple II, TRS-80 Model III, IBM-PC, Commodore 64/128 equipment. D.2

MICROBIOLOGY TECHNIQUES

Tutorial/Simulation covering various laboratory procedures. Program available for Apple II equipment. E.2

NEUROSCIENCE

NEUROMUSCULAR CONCEPTS

Tutorial covering muscle action potentials, use of electromyograph, contraction, muscle action and movement disorders. Program for Apple II equipment. B.2

PHARMACOLOGY

ILEUM

Simulates laboratory experiments investigating effects of drugs on the in vitro guinea pig ileum. Program available for Apple II and IBM-PC compatible equipment. B.1

PRINCIPLES OF PHARMACOLOGY

Tutorial covering history, drug absorption and distribution, biotransformation and elimination, mechanisms of action, and drug safety and efficacy. Program for Apple II equipment. B.2

PHYSIOLOGY

ABGAME

Tutorial and game providing practice in acid-base principles. Program available for IBM-PC compatible equipment. N.3

ACID-BASE PHYSIOLOGY SIMULATION

Simulation of acid-base disturbances based on Davenport Diagram. Program available for IBM-PC compatible equipment. I.1

BASIC HUMAN

Integrated systems model of human physiology. Program available for IBM-PC compatible equipment. R.1

BIOFEEDBACK

Part of 10 program package Experiments in Human Physiology. Experiments include biofeedback, conditioning, and perception measurements. Program available for Apple II equipment. H.1

BIOFEEDBACK MICROLAB

Package includes a pulse rate sensor that measures EMG, a thermistor probe to measure skin temperature, and an interface circuit that enables student to connect the sensors to the computer. Program available for Apple II and Commodore 64/128 equipment. H.1

THE BODY IN FOCUS

Tutorial for investigating body systems including skeletal, muscular, respiratory, cardiovascular, gastrointestinal, endocrine, and integumentary. Available for Apple II and IBM-PC compatible equipment. N.2

CALIBRATION

Part of 10 program package Experiments in Human Physiology. Temperature and timing functions are calibrated against standards. Program available for Apple II equipment. H.1

CAPEXCH

Simulation dealing with exchange at the capillary level. Available for IBM-PC compatible equipment. N.3

CARDIOVASCULAR FITNESS LAB

Provides students with everything they need in order to use the microcomputer to monitor cardiovascular activity. Program available for Apple II and Commodore 64/128 equipment. H.1

CARDIOVASCULAR INTERACTIONS

Cardiovascular Physiology simulation. Program available for IBM-PC compatible equipment. I.1

CARDIOVASCULAR PHYSIOLOGY PART I: PRESURE/FLOW RELATIONS

Tutorial dealing with a variety of calculations in the area of hemostatics/hemodynamics. Program available for IBM-PC compatible equipment. R.2

CARDIOVASCULAR PHYSIOLOGY PART II: REFLEX

Tutorial dealing with carotid sinus regulation of blood pressure, and reflex responses in hemorrhage and exercise. Program available for IBM-PC compatible equipment. R.2

CIRCSIM: A TEACHING EXERCISE ON BLOOD PRESSURE REGULATION

Simulated experiment based on a model of the baroreceptor reflex loop.

Program available for IBM-PC compatible equipment. R.2

CIRCSYST

Simulation of hemodynamics. Available for IBM-PC compatible equipment. N.3

DIGESTION

Tutorial covering digestion in simple organisms and humans. Program available for Apple II and TRS-80 Model III equipment. J.1

ENDOCRINE SYSTEM

Tutorial covering hormones, effects and problems. Program available for Apple II and TRS-80 Model III equipment. J.1

EXCRETION

Tutorial reviewing metabolic wastes, waste removal, and kidney function. Program available for Apple II and TRS-80 Model III equipment. J.1

VENDORS

A.1 Academic Hallmarks
P.O. Box 998
Durango, CO 81301
(303) 247-8738

B.1 BIOSOFT
22 Hills Road
Cambridge CB2 1JP, United Kingdom

P.O. Box 580
Milltown, NJ 08850

B.2 Biosource Software
2105 S. Franklin, Suite B
Kirksville, MO 63501
(816) 665-3678

C.1 Classroom Consortia Media, Inc.
57 Bay Street
Staten Island, NY 10301
(800) 237-1113
(800) 522-2210

C.2 COMpress
P.O. Box 102
Wentworth, NH 03282
(603) 764-5831

C.3 Compuware
15 Center Road
Randolph, NJ 07869
(201) 366-8540

C.4 CONDUIT
The University of Iowa
Oakdale Campus
Iowa City, IA 52242
(319) 335-4100

D.1 Datatech Software Systems
19312 East Eldorado Drive
Aurora, CO 90013

D.2 Diversified Education Enterprises
725 Main Street
Lafayette, IN 47901
(317) 742-2690

D.3 DYNACOMP, Inc.
1064 Gravel Road
Webster, NY 14580
(716) 671-6160
(800) 828-6772

E.1 Educational Activities, Inc.
P.O. Box 392
Freeport, NY 11520
(800) 645-3739
(516) 223-4666

E.2 Educational Materials and Equipment Co.
P.O. Box 17
Pelham, NY 10803
(914) 576-1121

E.3 EduTech, Inc.
303 Lamatine Street
Jamaica Plain, MA 02130
(617) 524-1774

H.1 HRM Software
175 Tompkins Avenue
Pleasantville, NY 10570
(914) 769-7496
(800) 431-2050

I.1 Indiana University School of Medicine
Department of Physiology and Biophysics
635 Barnhill Drive
Indianapolis, IN 46223

J.1 J & S Software
14 Vanderventer Avenue
Port Washington, NY 11050
(516) 944-9304

K.1 Kinko's Service Corporation
4141 State Street
Santa Barabara, CA 93110
(800) 235-6919
in CA (800) 292-6640
outside USA (800) 967-0192

L.1 Life Science Associates
1 Fennimore Road
Bayport, NY 11705
(516) 472-2111

N.1 National Resource for Computers in Life Science Education
Mail Stop RC-70
University of Washington
Seattle, WA 98195
(206) 548-6244

N.2 Neosoft, Inc.
CBS Interactive Learning
One Fawcett Place
Greenwich, CT 06836
(800) 227-2574

N.3 New Jersey Medical School
Joseph Boyle, MD
100 Bergen Street
Newark, NJ 07103
(201) 456-4464

O.1 Oakleaf Systems
P.O. Box 472
Decorah, IA 52101
(319) 382-4320

R.1 Randall, Dr. James
Department of Physiology
Myers Hall
Indiana University
Bloomington, IN 47405
(812) 335-1574

R.2 Rush Medical College
Drs. Joel Michael and Alan Rovick
Department of Physiology
1750 West Harrison Street
Chicago, IL 60612
(312) 942-6426
(312) 942-6567

S.1 Scott, Foresman and Company
1900 East Lake Ave.
Glenview, IL 60025
(312) 729-3000

S.2 Simpac Educational Systems
1105 North Main St.
Suite 11C
Gainesville, FL 32601
(904) 376-2049

S.3 Sliwa Enterprises, Inc.
2360-J George Washington Hwy
Yorktown, VA 23666
(804) 898-8386

U.1 University of Texas System Cancer Center
MDAH, Box 6
6723 Bertner
Houston, TX 77030
(713) 792-2581

0742-3233/88/$0.00 + 2.00

AIMS AND SCOPE

The goal of *Computers in Life Science Education* is to provide a means of communication among life science educators who anticipate or are currently employing the computer as an educational tool. The range of content includes, but is not limited to, articles focusing on computer applications and their underlying philosophy, reports on faculty/student experiences with computers in teaching environments, and software/hardware reviews in both basic science and clinical education settings.

INVITATION TO CONTRIBUTORS

Articles consistent with the goals of *Computers in Life Science Education* are invited for possible publication in the newsletter.

PREPARATION AND SUBMISSION OF MATERIAL

Articles submitted for publication should not exceed 2000 words and should be typewritten, double spaced, with wide margins. The original and two copies including two sets of figures and tables should be sent to the Editor: Dr. Harold Modell, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

Title page should include full title, list of authors, academic or professional affiliations, and complete address and phone number of the corresponding author.

Illustrations should be submitted as original drawings in India ink or sharp, unmounted photographs on glossy paper. The lettering should be such that it can be legible after reduction (width of one column = 5.7 cm).

Reference style and form should follow the "number system with references alphabetized" described in the Council of Biology Editors Style Manual. References should be listed in alphabetical order by the first author's last name, numbered consecutively, and cited in the text by these numbers.

RESPONSIBILITY AND COPYRIGHT

Authors are responsible for accuracy of statements and opinions expressed in articles. All authors submitting manuscripts will be sent a copyright transfer form to complete. The completed form must be returned before the work will be published.

SUBSCRIPTION INFORMATION

Computers in Life Science Education is published monthly by National Resource for Computers in Life Science Education, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Subscription rate is $30.00 for 12 issues, including postage and handling in the United States and Canada. Add $20.00 for postage (airmail) in Mexico and Europe and $23.00 for the rest of the world.

This newsletter has been registered with the Copyright Clearance Center, Inc. Consent is given for copying of articles for personal or internal use, or for the personal or internal use of specific clients. This consent is given on the condition that the copier pay through the Center the per-copy fee stated in the code on the first page for copying beyond that permitted by the US Copyright Law. If no code appears on an article, the author has not given broad consent to copy and permission to copy must be obtained directly from the author. This consent does not extend to other kinds of copying, such as for general distribution, resale, advertising and promotional purposes, or for creating new collective works.

Address orders, changes of address, and claims for missing issues to NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Claims for missing issues can be honored only up to three months for domestic addresses and six months for foreign addresses. Duplicate copies will not be sent to replace ones undelivered due to failure to notify NRCLSE of change of address.

Address editorial correspondence to Harold I. Modell, PhD, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. (BITNET MODELL@UWALOCKE)

POSTMASTER: Send address changes to *Computers in Life Science Education*, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

0742-3233/88/$0.00 + 2.00

VOLUME 5 NUMBER 6, JUNE 1988 CLSEE3 5(6)41-48, 1988 ISSN 0742-3233

COMPUTERS
IN LIFE
SCIENCE
EDUCATION

HAROLD I. MODELL
Department of Radiology
University of Washington
Seattle, Washington

MARCEL BLANCHAER
Department of Biochemistry
Faculty of Medicine
University of Manitoba
Winnipeg, Manitoba

THEODORE J. CROVELLO
Graduate Studies and Research
California State University, Los Angeles
Los Angeles, California

JAMES W. ECKBLAD
Department of Biology
Luther College
Decorah, Iowa

TSEGAYE HABTEMARIAM
School of Veterinary Medicine
Tuskegee University
Tuskegee, Alabama

DONNA LARSON
School of Nursing
Grand Valley State College
Allendale, Michigan

TERRY M. MIKITEN
Graduate School of Biomedical Sciences
University of Texas Health Science Center
San Antonio, Texas

JAMES E. RANDALL
Department of Physiology
Indiana University
Bloomington, Indiana

PATRICIA SCHWIRIAN
College of Nursing
Ohio State University
Columbus, Ohio

RICHARD STULL
College of Pharmacy
University of Arkansas
Little Rock, Arkansas

JAMES W. WOODS
Lister Hill National Center
for Biomedical Communications
National Library of Medicine
Bethesda, Maryland

DOROTHY WOOLEY-McKAY
Department of Biology
Glendale Community College
Glendale, Arizona

GLEN YOSHIDA
Department of Life Sciences
Los Angeles Southwest College
Los Angeles, California

NRCLSE

CONTENTS

AN OVERVIEW OF EXPERT SYSTEMS 41
Monica C. Nagy

WHERE'S THE SOFTWARE? 45

KEEPING ABREAST OF THE LITERATURE 47

AN OVERVIEW OF EXPERT SYSTEMS

Monica C. Nagy
Division of Instructional Development, University of Texas Health Science Center at San Antonio, San Antonio, Texas

Expert systems is a branch of artificial intelligence that has close ties to the life sciences. One of the first successful expert systems was developed by a team of researchers headed by Edward Shortliffe at Stanford University. The system, known as Mycin, gave advice on the diagnosis and treatment of infectious diseases and could perform as well as human experts or even out perform human experts in the field.[2] A recent bibliographic search revealed that twenty-four articles on expert systems have been published by health science journals in the last three years. This paper will examine the characteristics of an expert system, explain its functioning parts, and give a working example of an actual expert systems development project.

An expert system is a computer program that parallels the actions of a human expert consultant. The best way to understand an expert system is to examine the characteristics of a human expert consultant. Consider the following scenario.

Jane is the office manager of a small company. Being a high prestige organization, the appearance of the client waiting area is of the utmost importance. Several months ago, the company invested a large sum of money in indoor plants for the client waiting area. The plants gave the waiting area a friendly and relaxed atmosphere that

0742-3233/88/$0.00 + 2.00

many clients have since commented on. In the last week, however, the plants have started to look limp. Some of them have developed yellow spots on their leaves. Since Jane's bachelor degree in business administration did not prepare her for dealing with sick plants, she decides to hire an indoor plant consultant.

Jane's first step in hiring the plant consultant is to draw up a list of citeria. She decides that the plant consultant must have the following five qualities:

- KNOWLEDGE
  The consultant must be very knowledgeable about the problem at hand. Someone with several years of experience would be preferred. This person does not need to have a Ph. D. in botany, but they do need to know a good deal about the care of indoor plants.

- RELIABILITY
  The consultant should be reliable and capable of judging whether he or she is able to give advice on the problem. Far too often has Jane been stung by high-priced consultants who gave the wrong answer or would not admit that they could not solve the problem.

- ABILITY TO EXPLAIN WHY
  The consultant should also be able to explain why certain factors are important. The company cannot afford to hire a consultant every time the plants get sick. The consultant, therefore, should be able to explain what is wrong and give advice on how to prevent the problem from happening again.

- ABILITY TO EXPLAIN HOW
  Most of all, the consultant should be able to explain how he or she arrived at the conclusions and be able to justify the results. This provides a backup in case the results are unusual or do not seem logical.

- FRIENDLINESS
  Finally, an ideal consultant should be friendly and easy to work with. Although this criteria is often hard to meet, a friendly consultant makes for a much more pleasant experience and helps encourage further consultations in the future.

KEY FEATURES OF AN EXPERT SYSTEM PROGRAM

Let's examine each of Jane's five criteria for an expert human consultant and see how it applies to an expert system program. Jane's first requirement was that the consultant be knowledgeable and experienced in the problem area. An expert system program achieves this by containing all the rules and facts about a certain subject area. This collection of rules and facts is called the knowledge base.

Jane's second criterion, reliability, is another crucial factor in an expert system. An expert system program, just like its human counterpart, would be of little use if it were not reliable. To ensure reliability, expert system programs have a very narrow scope of expertise. At the present time, you would be hard pressed to find an expert system that could simulate the actions and experience of Ph.D. level botanist. You could, however, find one that gave advice on common houseplants. A colleague, Janise Richards, is developing one that diagnoses common houseplant ailments. When an expert system can give advice, the advice is usually in terms of certainty factors. A certainty factor is the degree to which an expert system thinks its advice is correct for that particular case. The certainty factors are reported either as percentages: "50% certainty of outcome #1," or as range: "On a scale of one to ten, your chances of #1 are 5."

Jane's next two criteria are the most import characteristics of an expert system program. The ability to answer how and why are, in my opinion, the two features that distinguish expert systems from other advice-giving programs. This ability also makes expert system programs a good learning tool. Rather than being simply a passive device, an expert system program can show you the logic behind its questions and its decisions.

Jane's final criterion, that the expert consultant be friendly and easy to work with, also applies to expert system programs. Most people would be reluctant to reuse any computer program with which they had a great deal of difficulty. For this reason, expert systems should strive to be user friendly.

To summarize, the key features of an expert system program are very similar to those of a good human expert consultant. An expert system contains a large amount of knowledge about a specific subject area. In order to ensure reliability, it tells the user when it can and cannot give advice. When it can give advice, it often uses certainty factors to indicate its degree of confidence in that advice. Finally expert systems help their users learn about the subject area by explaining their reasoning and their advice. Ideally, they should be friendly and easy to use.

COMPONENTS OF AN EXPERT SYSTEM

In order to acheive these goals, an expert system is constructed of three parts, the rule base, the database and the inference engine. The rule base holds all the expert information. It typically stores this information in the form of if-then rules. For example, a rule used in a plant diagnosis expert system might read:

```
If
        white, wooly spots appear on
           stem, leaves, or base of stem
and     leaves develop sticky patches
and     growth is stunted

then    diagnosis is mealy bugs
```

This type of if-then rule is also known as production rule.

The next part of an expert system is called the database. The database holds all the facts about the specific case. These facts are supplied by the user. In the case of Jane and her sick plants, the facts might be "plant appears to be limp" and "yellow patches on leaves." The database changes with each new case. The database and the rule base together are often termed the knowledge base of the expert system because these are the two parts that store the knowledge.

The final, and most important part is

the inference engine. The inference engine is the driver of the expert system. It is where all the actual "thinking" takes place. It uses the rules in the rule base and facts in the database to decide on the advice to give.

BUILDING AN EXPERT SYSTEM

Expert systems are easiest to build when the subject area is narrow and the rules are straight-forward and non-conflicting. For example, an expert system could be written to give advice on simple operations on a computer such as changing the default disk drive or displaying a directory.[1] The rules for performing these operations are usually listed in the computer's guide to operations. When the rules have already been written down, as in the case of a manual or quick reference guide, the creation of an expert system is made much easier. Many excellent expert systems have been created by first interviewing a number of human experts and then translating their expertise into rules. This process can be very time consuming and can also produce conflicting rules.

When there is no general consensus on the rules, or there exists a multitude of special exceptions, building an expert system becomes difficult. In college, I once gave a presentation on expert systems to a group of my fellow computer science majors. A short example program on how to identify a science fiction movie seemed to be appropriate since science fiction is of interest to most aspiring computer scientists. It quickly became apparent that science fiction movies were difficult to classify. As soon as one set of rules was finished, a conflicting example would arise. Almost everyone consulted had a different definition of a science fiction movie. Few could agree on even ten common factors. How would you classify *The Twilight Zone* ? What is the dividing line between science fiction and fantasy? Everyone agreed that a futuristic setting would be a good indicator. How far in the future the movie would have to be set could not be agreed upon. The presence of new technology was another factor commonly agreed upon. No consensus could be reached on how new the technology would have to be. I later came to find out that this debate has been going on for some time and shows no signs of being settled any time soon. A general consensus on the rules is necessary for building an expert system.

Let's see how all this information applies to an actual expert system development project. For the past year, I have worked on an expert system with Ernst Schelb, DMD, at the Dental School of the University of Texas Health Science Center at San Antonio. Our goal was to design and implement an expert system in the area of endodontics, to be used by second year dental students. The system was to be used for practice in the student lab. Endodontics is the area of dentistry that deals with the nerves and blood vessels on the inside of the tooth. Our expert system, known as "The Hurting Tooth Advisor," deals with diagnosing pain in a single suspect tooth. It does not deal with pain from other teeth or pain caused by problems outside of the mouth. Dr. Schelb felt that endodontics, as compared to other areas of dentistry, lent itself most to an expert system because of the small number of possible diagnoses. Also, the rules for diagnosis in endodontics are more straight-forward and less conflicting.

We began with a matrix that listed signs, symptoms and test outcomes across the top and possible diagnoses along one side. We then narrowed the signs, symptoms and tests down to three categories, description of the pain, clinical findings, and radiographic findings. We used the information in the matrix to write the rules. An expert system is much easier to create if the rules have already been formulated.

PROGRAM EXAMPLE

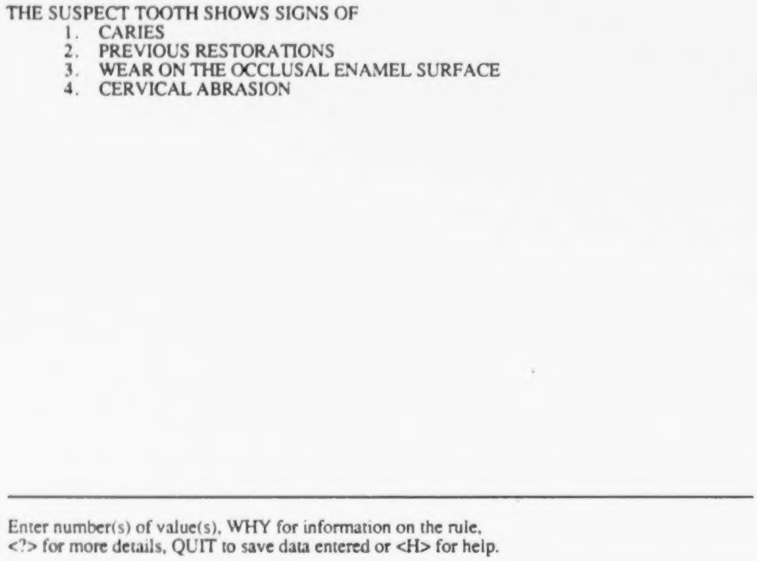
When it came time to transfer the rules to the computer, we chose to use the EXSYS expert system generator (EXSYS Inc., P.O. Box 75158, Station 14, Albuquerque, NM 87194). Generator programs greatly ease and accelerate the creation of an expert system. They take care of all the details. They usually provide the inference engine and a facility for displaying questions to the end user. They also allow the end user to ask why a question is being asked and, if they so desire, to see the rules that were used. Best of all, most generator programs are designed to be used by non-programmers.

Besides the features mentioned above,

```
Add rule <A> or <ENTER>, Edit rule <E>, Delete rule <D>, Move rule <M>,
Print <P>, Store/exit <S>, Run <R>, Options <O>, DOS <Ctrl-X>, Help <H>
```

FIGURE 1. The main editor screen.

EXSYS has a specialized editor for entering rules. This means that it prompts the person editing the rule for each of the rule's components (see Figure 1). Once the rules are entered, they can be tested right away by pressing "R" for run. The atecedent, or "if" part, of each rule is translated into a question for the student to answer. The expert system uses the rules themselves and the answers that the student has given thus far to determine which question will be asked next. For instance, in Figure 2, if the student answers that the tooth shows signs of caries, the next question would ask how extensive the caries were. If the student did not indicate that caries could be seen, the expert system would go on to the next category of questions. The student would not see the extra question on caries.



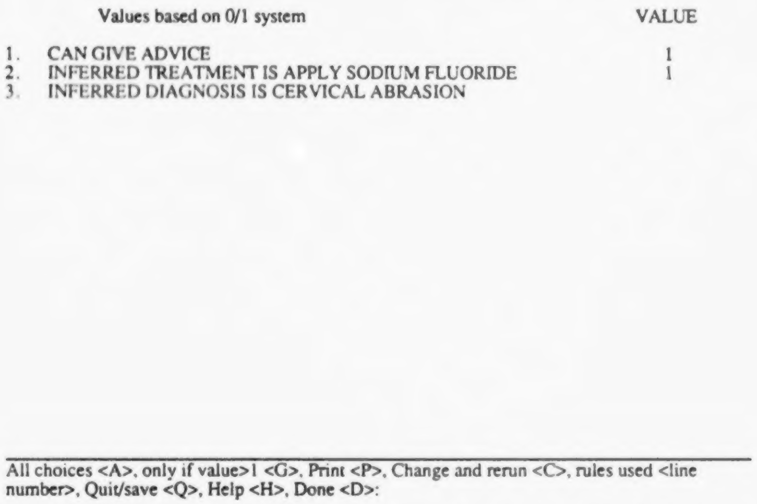
```
THE SUSPECT TOOTH SHOWS SIGNS OF
       1.  CARIES
       2.  PREVIOUS RESTORATIONS
       3.  WEAR ON THE OCCLUSAL ENAMEL SURFACE
       4.  CERVICAL ABRASION

Enter number(s) of value(s), WHY for information on the rule,
<?> for more details, QUIT to save data entered or <H> for help.
```

FIGURE 2. A question screen. At this point the student could enter the number corresponding to a selected choice, the word "WHY" to see the current rule, a "?" for more details, "QUIT" to save the information entered so far or "H" for help on using the expert system.

While using the expert system, a student can ask why a question is being asked by entering "WHY" as the response to a question. The student also has the option of seeing the rules as they are used. Once the student has answered all the questions, the possible diagnosis and treatment plan are displayed. At this point, the student can either print the advice, change some of their answers, and run the system again, or start over from the beginning (see Figure 3).

The Hurting Tooth Advisor is now in a prototype stage, meaning that it gives accurate results only for a few chosen cases. We hope to develop this into a fully operational system.

In conclusion, an expert system is a computer program that simulates the human capabilities of knowledge, reliability, the ability to explain the importance of key factors, the ability to explain how a conclusion is reached, and the ability to be friendly and easy to use. Expert systems attain these abilities by organizing information into a rule base and a database. They also contain an inference engine that drives the whole process. Finally, an expert system is easiest to build in an area that has well codified rules and guidelines that are straight-forward and non-conflicting.



```
                 Values based on 0/1 system                          VALUE

1.   CAN GIVE ADVICE                                                   1
2.   INFERRED TREATMENT IS APPLY SODIUM FLUORIDE                       1
3.   INFERRED DIAGNOSIS IS CERVICAL ABRASION

All choices <A>, only if value>1 <G>, Print <P>, Change and rerun <C>, rules used <line
number>, Quit/save <Q>, Help <H>, Done <D>:
```

FIGURE 3. The conclusions are displayed in terms of certainty factors. In this case, the certainty factor will either be zero, for false, or one, for true.

REFERENCES

1. Nagy, T, D Gault, and M Nagy. Building Your First Expert System. Aston-Tate, Culver City, CA, 1985.
2. Winston, PH and KA Predergast (eds). The AI Business: The Commercial Uses of Artificial Intelligence. MIT Press, Cambridge, MA, 1984.

0742-3233/88/$0.00 + 2.00

WHERE'S THE SOFTWARE?

In the past, we have published lists of life science software sources and programs or program areas available through them. The following list is presented as the latest in a continuing effort to make colleagues aware of potential resources. As in the past, no attempt has been made by NRCLSE to review these materials.

This month's listings continue last month's and are arranged by content area. Each item includes a vendor code relating the software to the vendors appearing at the end of the software lists.

If you have found specific software helpful in your teaching efforts, please share your good fortune by letting us know about the program(s) and supplier(s) so that we can make this information available through future Where's the Software lists. Send pertinent information to Dr. Harold Modell, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195 or send us a note on BITnet. Our BITnet address is MODELL@ UWALOCKE.

PHYSIOLOGY

CONCEPTS IN THERMOGRAPHY

Tutorial covering basic DC concepts, peripheral vascular physiology, detecting skin temperature, amplifiers, and processing DC signals. Program for Apple II equipment. B.2

EXERCISE EXPERIMENTS

Part of 10 program package Experiments in Human Physiology. The effect of exercise and physical condition on heart rate, breathing rate, and skin temperature is investigated. Program available for Apple II equipment. H.1

GAS DIFFUSION IN THE LUNG

Simulation of oxygen and CO2 transfer between alveolar air and blood. Program available for IBM-PC compatible equipment. I.1

HEART RATE

Part of 10 program package Experiments in Human Physiology. Light and light sensor for measuring and recording heart rate. Program available for Apple II equipment. H.1

HOMEOSTASIS- THERMOREGULATION

Part of 10 program package Experiments in Human Physiology. Students investigate the body's ability to maintain a constant internal temperature by subjecting a volunteer to mild temperature excursion while recording and displaying skin and body temperature. Program available for Apple II equipment. H.1

HUMAN BODY-STRUCTURE AND FUNCTION

Simulation covering joint movement, movement of food through digestive system, and enzyme activity. Program available for Apple II equipment. S.1

MODEL NEURON

Simulation of the behavior of an isolated neuron. Program available for Macintosh equipment. K.1

MUSCLE MECHANICS: A COMPUTER-SIMULATED EXPERIMENT

Simulated experiment that permits the user to determine either the length-tension or the force-velocity relationship of a skeletal muscle. Program available for IBM-PC compatible equipment. R.2

NERVOUS SYSTEM

Tutorial covering nerves, reflexes, and chemical transfer of impulses. Program available for Apple II and TRS-80 Model III equipment. J.1

PHYSIOLOGICAL DATA SIMULATION

25 simulations covering aspects of physiology. Program available for Apple II and IBM-PC compatible equipment. 0.1

PROBLEMS IN FLUID COMPARTMENT RE-DISTRIBUTION

Tutorial covering solution of simple problems of fluid compartment changes in the face of perturbations. Program available for IBM-PC compatible equipment. R.2

PSYCHOLOGICAL STRESS-LIE DETECTOR

Part of 10 program package Experiments in Human Physiology. The physiological response to the stress of a frustrating and abusive quiz is measured. Program available for Apple II equipment. H.1

PULMONARY MECHANICS

Tutorial and simulation dealing with pulmonary mechanics. Available for IBM-PC compatible equipment. N.3

RESPIRATION RATE

Part of 10 program package Experiments in Human Physiology. A napping subject is monitored for heart and breathing rate. Results are compared to the data acquired when the subject is awake. Program available for Apple II equipment. H.1

RESPONSE-TIME

Part of 10 program package Experiments in Human Physiology. Users measure finger reaction times with a bright light stimulus (sensor included). Program available for Apple II equipment. H.1

RESPONSE-TIME INVESTIGATIONS

Part of a 10 program package Experiments in Human Physiology. The effects on reaction times of stimulus type and response location are studied. Program available for Apple II equipment. H.1

RESPSYST, GASEXCH

Simulations dealing with pulmonary gas exchange. Available for IBM-PC compatible equipment. N.3

SIMULATIONS IN PHYSIOLOGY - THE RESPIRATORY SYSTEM

Series of 12 simulations dealing with respiratory mechanics, gas exchange, chemoregulation and acid-base balance. Program available for Apple II, IBM-PC compatible, and Macintosh equipment. N.1

SKELETAL MUSCLE ANATOMY/ PHYSIOLOGY

Tutorial covering three muscle categories, skeletal muscle microstructure, sliding filament theory, motor units, and lever systems. Program for Apple II equipment. B.2

SKELETAL MUSCLE MECHANICS

Set of six simulations dealing with muscle physiology. Program available for IBM-PC compatible equipment. I.1

SKILLS IN ELECTROMYOGRAPHY

Tutorial covering skin preparation, reducing EMG artifact, testing a myograph's operation, electrode location, and preventing shock hazards. Program for Apple II equipment. B.2

SKIN TEMPERATURE

Part of a 10 program package Experiments in Human Physiology. Temperature probe (included) senses body and skin temperatures. Program available for Apple II equipment. H.1

POPULATION DYNAMICS

COEXIST:Population Dynamics

Simulation of the growth of two populations either independently or in competition for the same limited resources. Program available for Apple II equipment. C.4

ISLAND BIOGEOGRAPHY

Three simulations of island communities dealing with the relationship between island area and number of species, colonization of a new island, and island immigration and extinction. Program available for Apple II equipment. C.4

LIMITS

Simulation of the effects of growth on world population, pollution, food supply, industrial output, and natural resources. Program available for Apple II, PET/CBM and TRS-80 Model III equipment. C.3

0742-3233/88/$0.00 + 2.00

MARK & RECAPTURE

Simulation of mark and recapture experiments to explore three models for estimating population sizes. Program available for Apple II equipment. C.4

POP

Simulation of three growth models (exponential, logistical, and logistical with low density). Program available for Apple II, PET/CBM, and TRS-80 Model III equipment. C.3

POPGRO-POPULATION GROWTH SIMULATION

Simulation of unlimited growth (J-curve), limited growth (S-curve) and limited growth with response lag time (S-curve with oscillations) models of population growth. Program available for Apple II, TRS-80 Models I and III, IBM-PC, and Commodore 64/128 equipment. D.2

POPULATION FLUCTUATIONS

Tutorial covering factors influencing population growth. Program available for Apple II, TRS-80 Models I and III equipment. E.2

POPULATION GROWTH

Simulation dealing with exponential and density-dependent gowth. Program for Apple II equipment. C.2

POPULATION GROWTH

Simulation of population growth. The package compares and contrasts the geometric or exponential growth model with the logistic or Verhulst-Pearl growth model. Program available for Apple II equipment. C.4

POPULATON SIZES

Simulation dealing with a dynamic population. Program for Apple II equipment. C.2

SUBSTANCE ABUSE

DRINKING AND NOT DRINKING

Tutorial designed to augment strategies for the prevention of substance abuse. Includes facts about drinking and the effects of alcohol. Program available for Apple II equipment. K.1

INTRODUCTION TO PSYCHOACTIVE DRUGS

Tutorial designed to augment strategies for the prevention of psychoactive drug abuse. Program available for Apple II equipment. K.1

KEEP OFF THE GRASS

Tutorial designed to augment strategies for the prevention of marijuana abuse. Program available for Apple II equipment. K.1

SIX CLASSES OF PSYCHOACTIVE DRUGS

Tutorial designed to augment strategies for the prevention of psychoactive drug abuse. Program available for Apple II equipment. K.1

SUBSTANCE ABUSE DATA BASE

Database containing contact information on substance abuse organizations. Program available for Apple II equipment. K.1

ZOOLOGY

ZOOLOGY I

Tutorial covering the general charactistics, structures, and functions that define the major invertebrate phyla. Program available for Apple II and IBM-PC compatible equipment. S.3

ZOOLOGY II

Tutorial covering physiology in the Phylum Chordata. Program available for Apple II and IBM-PC compatible equipment. S3

MISCELLANEOUS

BAFFLES, BAFFLES II

Game to help students develop deductive reasoning and problem solving skills. Program available for Apple II (BAFFLES) and IBM-PC compatible (BAFFLES II) equipment. C.4

BALANCE-PREDATOR-PREY SIMULATION

Simulation of the effects of food supply, carrying capacity, environmental conditions, and external pressures or predator/prey relationships. Program available for Apple II, TRS-80 Models I and III, IBM-PC, and Commodore 64/128 equipment. D.2

BLANCHAER CLINICAL CASE STUDIES

Eight simulations of clinical syndromes. Program available for Apple II equipment. B.1

CLASSIFY-CLASSIFICATION KEY PROGRAM

Presents an unclassified set of characteristics and labels for classification at various levels. Program available for Apple II, TRS-80 Model III, IBM-PC, and Commodore 64/128 equipment. D.2

GRADE KEEPER - PC

Grade book manager that handles classes up to 300 students, up to 25 grades per student. Program available for IBM-PC compatible equipment. O.1

GRADEBK

Program for the analysis of a large set of grades. Program available for IBM-PC compatible equipment. I.1

LABPLOT

Allows the Apple II with any A/D converter card to be used as a multipen chart recorder or as an X/Y plotter. B.1

LIFE TABLES AND THE LESLIE MATRIX

Tutorial-simulation dealing with the basic life table and Leslie Matrix. Program available for Apple II equipment. C.4

MALARIA

Simulation of the effects of various types of malaria epidemic controls. Program available for Apple II, PET/CBM, and TRS-80 Model III equipment. C.3

MULTI-Q

A general purpose question creation and presentation system. Program available for Apple II and IBM-PC compatible equipment. B.1

PREDATION

Simulation of predator-prey interactions. Program available for Apple II equipment. C.4

PREDATION EQUILIBRIA

Simulations of equilibrium models of predator-prey interaction. Program available for Apple II equipment. C.4

"Q" EDUCATIONAL AUTHORING SYSTEM

Authoring system for tutorial and assessment material. Allows incorporation of graphics and videodisc material. Program available for IBM-PC compatible equipment. B.1

RATS

Simulation of rat control in city or apartment by sanitation and various poisons. Program for Apple II, PET/CBM, and TRS-80 Model III equipment. C.3

STERL

Simulation exploring effectiveness of pest control methods. Program available for Apple II, PET/CBM, and TRS-80 Model III equipment. C.3

TRIBBLES, TRIBBLES Revisited

Simulation to introduce students to the scientific method. Programs available for Apple II (Tribbles) and IBM-PC compatible (Tribbles revisited) equipment. C.4

VENDORS

A.1 Academic Hallmarks
P.O. Box 998
Durango, CO 81301
(303) 247-8738

B.1 BIOSOFT
22 Hills Road
Cambridge CB2 1JP, United Kingdom

P.O. Box 580
Milltown, NJ 08850

B.2 Biosource Software
2105 S. Franklin, Suite B
Kirksville, MO 63501
(816) 665-3678

C.1 Classroom Consortia Media, Inc.
57 Bay Street
Staten Island, NY 10301
(800) 237-1113
(800) 522-2210

C.2 COMpress
P.O. Box 102
Wentworth, NH 03282
(603) 764-5831

C.3 Compuware
15 Center Road
Randolph, NJ 07869
(201) 366-8540

C.4 CONDUIT
The University of Iowa
Oakdale Campus
Iowa City, IA 52242
(319) 335-4100

D.1 Datatech Software Systems
19312 East Eldorado Drive
Aurora, CO 90013

D.2 Diversified Education Enterprises
725 Main Street
Lafayette, IN 47901
(317) 742-2690

D.3 DYNACOMP, Inc.
1064 Gravel Road
Webster, NY 14580
(716) 671-6160
(800) 828-6772

E.1 Educational Activities, Inc.
P.O. Box 392
Freeport, NY 11520
(800) 645-3739
(516) 223-4666

E.2 Educational Materials and Equipment Co.
P.O. Box 17
Pelham, NY 10803
(914) 576-1121

E.3 EduTech, Inc.
303 Lamatine Street
Jamaica Plain, MA 02130
(617) 524-1774

H.1 HRM Software
175 Tompkins Avenue
Pleasantville, NY 10570
(914) 769-7496
(800) 431-2050

I.1 Indiana University School of Medicine
Department of Physiology and Biophysics
635 Barnhill Drive
Indianapolis, IN 46223

J.1 J & S Software
14 Vanderventer Avenue
Port Washington, NY 11050
(516) 944-9304

K.1 Kinko's Service Corporation
4141 State Street
Santa Barabara, CA 93110
(800) 235-6919
in CA (800) 292-6640
outside USA (800) 967-0192

L.1 Life Science Associates
1 Fennimore Road
Bayport, NY 11705
(516) 472-2111

N.1 National Resource for Computers in Life Science Education
Mail Stop RC-70
University of Washington
Seattle, WA 98195
(206) 548-6244

N.2 Neosoft, Inc.
CBS Interactive Learning
One Fawcett Place
Greenwich, CT 06836
(800) 227-2574

N.3 New Jersey Medical School
Joseph Boyle, MD
100 Bergen Street
Newark, NJ 07103
(201) 456-4464

O.1 Oakleaf Systems
P.O. Box 472
Decorah, IA 52101
(319) 382-4320

R.1 Randall, Dr. James
Department of Physiology
Myers Hall
Indiana University
Bloomington, IN 47405
(812) 335-1574

R.2 Rush Medical College
Drs. Joel Michael and Alan Rovick
Department of Physiology
1750 West Harrison Street
Chicago, IL 60612
(312) 942-6426
(312) 942-6567

S.1 Scott, Foresman and Company
1900 East Lake Ave.
Glenview, IL 60025
(312) 729-3000

S.2 Simpac Educational Systems
1105 North Main St.
Suite 11C
Gainesville, FL 32601
(904) 376-2049

S.3 Sliwa Enterprises, Inc.
2360-J George Washington Hwy
Yorktown, VA 23666
(804) 898-8386

U.1 University of Texas System Cancer Center
MDAH, Box 6
6723 Bertner
Houston, TX 77030
(713) 792-2581

KEEPING ABREAST OF THE LITERATURE

The following citations are presented as part of a quarterly feature in CLSE designed to help readers become aware of current literature pertinent to computer applications in life science education.

Allan DM et al: Issues in the adoption of a new educational technology. Comput Methods Programs Biomed 25(2):103-109, 1987.

Allen BS et al: Training interactive video designers. J Instructional Development 9(2):19-28, 1986.

Apostolides Z: Computer assisted instruction in biochemistry. Biochemical Education 15(3):129-133, 1987.

Crowell P: An international medical teaching image bank. Optical Information Systems 6(6):448-450, 1986.

DeLoughry TJ: Videodiscs gain a new role in classrooms as medium to simulate real-life situations. Chronicle of Higher Education 34(14):A13, 16, 17, 1987.

Dooling SL: Designing computer simulations. Comput Nurs 5(6):219-224, 1987.

Duchastel P: Intelligent computer assisted instruction systems: the nature of learner control. J Educ Comp Res 2(3):379-393, 1986.

Eaton N: Teaching computing to nursing students. Senior Nurse 7(3):28-29, 1987.

Eisenberg H et al: computer assisted teaching program: a pulmonary patient management problem. Int J Clin Monit Comput 4(4):195-197, 1987.

Ghislandi P et al: Reconstructive surgery of the trachea: an interactive videodisc. Optical Information Systems 6(6):494-500, 1986.

Hannafin MJ et al: Perspectives in the design of interactive video: beyond tape versus disc. Journal of Research and Development in Education 21(1):44-60, 1987.

Harasym PH et al: MAPS: a microcomputer-aided patient simulation.

0742-3233/88/$0.00 + 2.00

Med Teach 9(1):43-52, 1987.

Harvey FA: Emerging digital optical disc technologies: an opportunity and a challenge for educational researchers. AECT-RTD Newsletter 12(1):2-10, 1987.

Hebda T: A profile of the use of computer assisted instruction within baccalaureate nursing education. Comput Nurs 6(1):22-29, 1988.

Hostetler JC et al: A communication device for interfacing slide/audio tape programs with the microcomputer for computer-assisted self-instruction. Collegiate Microcomputer 5(4):343-348, 1987.

Howard EP: Use of a computer simulation for the continuing education of registered nurses. Comput Nurs 5(6):208-213, 1987.

Jensh RP: Use of interactive-video programs in education in basic medical science. J Med Educ 62(11):942-944, 1987.

Johnston R et al: Computers in respiratory therapy. AARC Times 11(8):16, 45, 1987.

Kordas M et al: Personal computers in teaching quantitative aspects in undergraduate physiology. Med Educ 21(6):468-470, 1987.

Kozma RB et al: Regarding innovation: 1987 EDUCOM/NCRIPTAL higher education software awards. EDUCOM-Bulletin 22(3):18-26, 1987.

Larson CE: Use of the microcomputer as a tool for subjective grading. Comput Nurs 5(5);186-191, 1987.

Lee AS et al: AI/LEARN network. The use of computer-generated graphics to augment the educational utility of a knowledge-based diagnostic system (AIR/RHEUM). J Med Syst 11(5):349-358, 1987.

Lukesh SS: Microcomputer use in higher education: summary of a survey. EDUCOM Bulletin 22(3):13-17, 1987.

Microcomputers in Education Conference. J Comp Math Sci Teach 6(4):53-55, 1987.

Miller M: Educational opportunities of an interactive video-based information system. CAUSE/EFFECT 10(6):40-43, 1987.

Miller MD: Simulations in medical education: a review. Med Teach 9(1):35-41, 1987.

Miller RL: Interactive instruction delivery and learning technology in the health care sciences, Orlando FL, 18-20 February 1987. Videodisc Monitor 5(4):16-19, 1987.

Procter PM: To boldly go...a strategy for the development, implementation and understanding of computer-assisted learning in nursing education in England. Interactive Learning International 4(1):17-19, 1987.

Richards B et al: Computer aided learning in the NHS. Interactive Learning International 4(1):13-16, 1987.

Rubincam I: Frequently cited authors in the literature on computer applications to education. J Comp-Based Instr 14(4):150-156, 1987.

Sheehan MC et al: IUWare and computing tools: Indiana University's approach to low-cost software. Collegiate Microcomputer 5(4):305-310, 1987.

Simpson D et al: Application of a frame-based computer-aided learning system in clinical chemistry Med Educ 21(5):399-404, 1987.

Tchogovadze GG: Some steps towards intelligent computer tutoring systems. Education and Computing 2(4):273-277, 1986.

Tymchyshyn P: Do-it-yourself software. Am J Nurs 87(12):1683, 1987.

Watt ME et al: A tape-based system of interactive video for computerized self-instruction. Med Teach 9(3):309-315, 1987.

Weiner EE et al: Will higher education lose in the game of laser tag?... computer assisted interactive video instruction. Comput Nurs 5(5):163-164, 1987.

Whiteside MF et al: Preparing allied health faculty to use and develop computer-assisted instruction. J Allied Health 16(3):247-254, 1987.

Wigton RS: The use of computer simulation in teaching clinical diagnosis. Comput Methods Programs Biomed 25(2):111-114, 1987.

SUBSCRIPTION INFORMATION

Computers in Life Science Education is published monthly by National Resource for Computers in Life Science Education, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Subscription rate is $30.00 for 12 issues, including postage and handling in the United States and Canada. Add $20.00 for postage (airmail) in Mexico and Europe and $23.00 for the rest of the world.

This newsletter has been registered with the Copyright Clearance Center, Inc. Consent is given for copying of articles for personal or internal use, or for the personal or internal use of specific clients. This consent is given on the condition that the copier pay through the Center the per-copy fee stated in the code on the first page for copying beyond that permitted by the US Copyright Law. If no code appears on an article, the author has not given broad consent to copy and permission to copy must be obtained directly from the author. This consent does not extend to other kinds of copying, such as for general distribution, resale, advertising and promotional purposes, or for creating new collective works.

Address orders, changes of address, and claims for missing issues to NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Claims for missing issues can be honored only up to three months for domestic addresses and six months for foreign addresses. Duplicate copies will not be sent to replace ones undelivered due to failure to notify NRCLSE of change of address.

Address editorial correspondence to Harold I. Modell, PhD, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. (BITNET MODELL@UWALOCKE)

POSTMASTER: Send address changes to *Computers in Life Science Education*, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

VOLUME 5 NUMBER 7, JULY 1988

CLSEE3 5(7) 49-56, 1988 ISSN 0742-3233

COMPUTERS IN LIFE SCIENCE EDUCATION

HAROLD I. MODELL
Department of Radiology
University of Washington
Seattle, Washington

MARCEL BLANCHAER
Department of Biochemistry
Faculty of Medicine
University of Manitoba
Winnipeg, Manitoba

THEODORE J. CROVELLO
Graduate Studies and Research
California State University, Los Angeles
Los Angeles, California

JAMES W. ECKBLAD
Department of Biology
Luther College
Decorah, Iowa

TSEGAYE HABTEMARIAM
School of Veterinary Medicine
Tuskegee University
Tuskegee, Alabama

DONNA LARSON
School of Nursing
Grand Valley State College
Allendale, Michigan

TERRY M. MIKITEN
Graduate School of Biomedical Sciences
University of Texas Health Science Center
San Antonio, Texas

JAMES E. RANDALL
Department of Physiology
Indiana University
Bloomington, Indiana

PATRICIA SCHWIRIAN
College of Nursing
Ohio State University
Columbus, Ohio

RICHARD STULL
College of Pharmacy
University of Arkansas
Little Rock, Arkansas

JAMES W. WOODS
Lister Hill National Center
for Biomedical Communications
National Library of Medicine
Bethesda, Maryland

DOROTHY WOOLEY-McKAY
Department of Biology
Glendale Community College
Glendale, Arizona

GLEN YOSHIDA
Department of Life Sciences
Los Angeles Southwest College
Los Angeles, California

NRCLSE

CONTENTS

A GRAPHIC COMPUTER LANGUAGE FOR PHYSIOLOGY SIMULATIONS 49
J.W. Kiel and A.P. Shepherd

A GRAPHIC COMPUTER LANGUAGE FOR PHYSIOLOGY SIMULATIONS

J.W. Kiel and A.P. Shepherd
Department of Physiology, University of Texas Health Science Center, San Antonio, Texas

Physiologists and other life scientists can use mathematical models profitably to create and test new scientific theories as well as to demonstrate to their students the behavior of complex biological systems. Unfortunately, creating such models often requires more computer programming expertise or more time and effort than the investigator can afford to invest in a model whether it is a research tool or a didactic device. Therefore, we were intrigued by LabView*, a graphic programming language that recently became available for the Macintosh computer.

Because physiologists generally think of organ systems in terms of block diagrams and feedback loops, we thought perhaps a graphic programming language would make constructing a mathematical model easier, less time-consuming, and more intuitive than conventional computer languages.

Therefore, the purpose of this communication is to report our experience using LabView to construct mathematical models of physiological systems.

Because LabView was originally developed to control laboratory instruments and to collect and analyze data, a LabView program can be thought of metaphorically as a "virtual instrument." A virtual instrument consists of a front panel and an executable block diagram. In one window on the com-

---

* The graphic programming language is actually called G, but it is better known by the trade name LabView, an acronym for laboratory virtual instrument engineering workbench. The LabView package consists of four 3.5 inch disks and a two-volume manual. It is available from National Instruments, 12109 Technology Blvd., Austin, Texas, 78727-9119, and it runs on a 1Mb Mac Plus, SE, or II. An external floppy or hard disk is required.

0742-3233/88/$0.00 + 2.00

puter screen, the front panel displays the various input and output controls available to the user or programmer: graphic representations of switches, dials, knobs, digital or analog meters, strip-charts, etc. The appearance of these controls or display devices changes to illustrate the data going into or out of the virtual instrument.

A second window contains the block diagram that constitutes the program that the computer executes. In the block diagram, numeric variables, display devices, program control structures such as For-Next loops, and arithmetic operations are nodes represented graphically by icons. The programmer uses various menus to obtain the desired icons and then places them in the block diagram. "Wires" connecting the icons define the path of data flow from one node to the next. The execution environment is inherently parallel and data-driven, (ie, each icon or node executes its particular function when all necessary input data are available to it).[5] The output of that particular node is then passed on to the next. The block diagram of one virtual instrument can even contain other virtual instruments within it. Thus, previously programmed routines can easily be incorporated into a more elaborate model. According to a recent report, "the intended user base for LabView includes engineers and scientists with no programming experience or limited experience with a simple language like BASIC." [5] Therefore, being only moderately proficient in BASIC, we felt appropriately qualified to evaluate LabView as a programming language for physiological simulations. To do so, we programmed two well-known cardiovascular models in LabView. In the rest of this report, we describe the programs themselves, our experience in creating them, and our perceptions of the strengths and weaknesses of LabView as a method for modeling physiological systems.

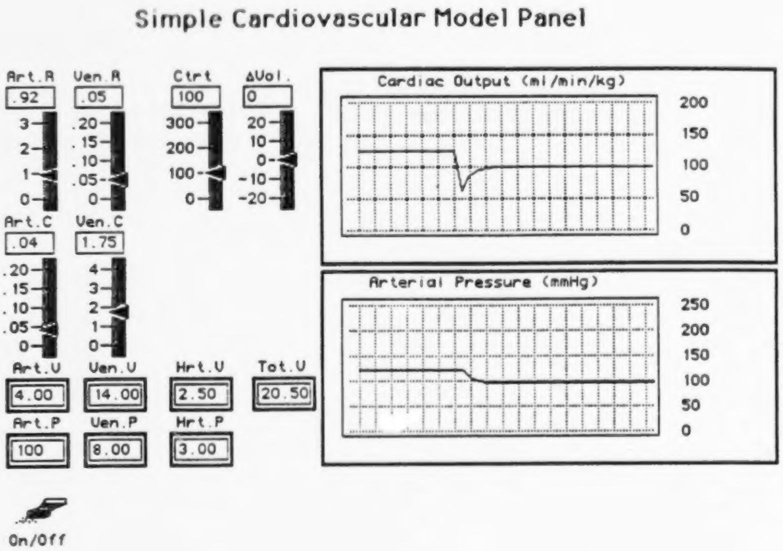
A SIMPLE CARDIOVASCULAR MODEL

The following model of the cardiovascular system was originally proposed by Guyton et al.[2] Rothe[4] later developed it into a teaching tool for courses in cardiovascular physiology. The model was designed to simulate the interaction between the heart and the peripheral vascular system and to demonstrate homeostatic responses to a variety of perturbations to the cardiovascular system (eg, exercise, cardiac failure, and hemorrhage).

The model consists of three compartments: a single-chambered heart, an artery, and a vein. Under steady-state conditions, each compartment contains a specific volume of blood. The pressure in each compartment is determined by the compartment's compliance and its blood volume. Blood flow between compartments is a function of the pressure gradients and resistances between compartments. To simulate the Frank-Starling mechanism crudely, cardiac output is computed simply as a linear function of heart volume. Although there are no "reflexes" *per se*, the appropriate cardiovascular effectors (ie, arterial resistance and compliance, venous resistance and compliance, and cardiac contractility) can be modified by the user. In addition, there is also a provision for simulating hemorrhage or transfusion by increasing or decreasing the total blood volume.

Figure 1 shows the "front panel" of the cardiovascular model as it appears on the Macintosh screen. The slide switches permit the user to change the resistances (Art.R and Ven.R) and compliances (Art.C and Ven.C) of the two vascular compartments, cardiac contractility (Ctrt), and the total blood volume (ΔVol). The two strip-charts continuously display the cardiac output and arterial pressure. The digital indicators for each compartment show the current numerical values for the blood volumes (Art.V, Ven.V, and Hrt.V) and pressures (Art.P, Ven.P, and Hrt.P) as well as the total blood volume (Tot.V). In Figure 1, the input and output values shown on the slide switches and other indicators are the initial default values specified by Rothe.[4]

Figure 2 shows the block diagram for the simple cardiovascular model. All of the actual calculations are performed



Simple Cardiovascular Model Panel

Art.R .92
Ven.R .05
Ctrt 100
ΔVol. 0
Art.C .04
Ven.C 1.75
Art.V 4.00
Ven.V 14.00
Hrt.V 2.50
Tot.V 20.50
Art.P 100
Ven.P 8.00
Hrt.P 3.00

FIGURE 1. Front panel of a simple cardiovascular model. A window on the computer screen shows the four types of control and display devices used in this model. Slide switches select values for cardiac contractility (Ctrt), the rate of hemorrhage or infusion (ΔVol), and arterial and venous resistances (Art.R and Ven.R) and compliances (Art.C and Ven.C). Digital indicators show blood volumes in the three compartments, and strip-chart simulators provide a continuous record of cardiac output and arterial pressure. A binary on-off switch stops and starts program execution.

0742-3233/88/$0.00 + 2.00

within a While-Wend Loop activated by an On/Off switch located on the front panel. In the diagram, the On/Off switch is "wired" to the "recirculation terminal" (counterclockwise arrow) at the bottom right-hand corner. The While-Wend Loop is used to provide continuous operation and to store the compartmental volumes for use in the next iteration. These values are stored from one iteration to the next by the three shift-registers (boxed arrows) located on the left and right borders of the While-Wend Loop structure. The three numeric constants wired to the shift-registers on the left border of the While-Wend Loop initialize the shift-registers and provide the starting values of the blood volumes in the three compartments.

Simple Cardiovascular Model Diagram

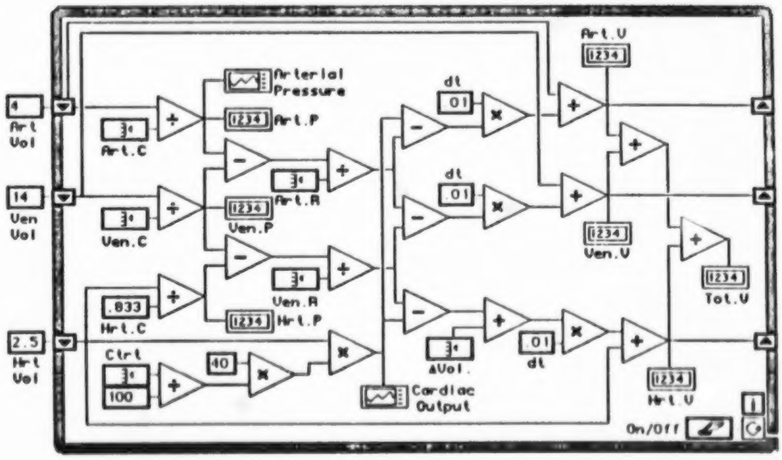


FIGURE 2. Block diagram of a simple cardiovascular model. A LabView diagram is the program that the computer executes. Each icon represents the arithmetic operation denoted by its symbol or corresponds to a switch or display device on the front panel shown in Figure 1. "Wires" define the path of data flow. For details of operation, see text.

Within the While-Wend Loop, the program proceeds from left to right. The first step in the program is to calculate the pressures in the three compartments by dividing the volumes specified in the three shift-registers by the corresponding compliance values selected on the front panel. These calculations are performed by three division icons. For example, to calculate the pressure in the arterial compartment, the arterial shift-register is wired to the upper terminal (the numerator) of one division icon, and the arterial compliance slide switch control is wired to the bottom terminal (the denominator). The output terminal of the division icon (the quotient) is wired to both a strip-chart indicator and a numeric indicator to display the arterial pressure on the front panel. The same procedure is used to calculate the pressures in the venous and cardiac compartments.

The next step in the program is to calculate the pressure gradients between the arterial and venous compartments and between the venous and cardiac compartments. These pressure differences are calculated by wiring the three division output terminals into two subtraction icons. The pressure differences are then divided by the arterial and venous resistances to determine the blood flow from the arterial to the venous compartment and from the venous compartment to the heart.

As shown in the lower portion of Figure 2, cardiac output is simply a linear function of heart volume and is calculated by multiplying the heart volume by the slope of the relationship between heart volume and cardiac output. However, note that the slope of this relationship depends on the cardiac contractility (Hrt. Ctrt) and that cardiac contractility can be changed from the default valve (100%) by using the slide switch on the front panel.

Under steady-state conditions, blood flow through the three compartments will be equal. However, following any perturbation, a transient imbalance in blood flow between any two compartments will redistribute the blood volume. Therefore, the next step in the program is to calculate the volume shifts among the three compartments (ie, cardiac output minus arterial runoff, arterial runoff minus venous return, and venous return minus cardiac output). These differences between each compartment's inflow and outflow are then multiplied by an increment in time (dt). The result of this integration is added to the old volume from the previous iteration (from the shift-register on the left) to yield the new instantaneous volume in each compartment. The new instantaneous volume is then passed to the shift register on the right and stored until the next iteration. Finally, the slide switch ΔVol allows the user to select a rate at which blood volume is gained or lost through transfusion or hemorrhage.

A MODEL OF PULSE PRESSURE

To show a slightly more elaborate model programmed in LabView and to demonstrate other capabilities of LabView not illustrated in the previous example, we present a model of the arterial pressure pulse that was originally published by Coleman and Sias[1] and later used by Randall for didactic purposes.[3] The model was designed to demonstrate the physics of the arterial pressure pulse and to show how the amplitude of the arterial pressure wave is affected by stroke volume, arterial compliance, and the ventricular ejection rate. The model consists of a single ventricle and an elastic arterial compartment. We modified the Coleman-Sias-Randall model so that the ventricle receives a variable venous return and has an adjustable heart rate. These two factors determine the stroke volume and the rate of ventricular ejection into the arterial compartment. The

0742-3233/88/$0.00 + 2.00

instantaneous volume in the arterial compartment is set by the difference between ventricular ejection and the peripheral runoff. The instantaneous volume and the arterial compliance determine the instantaneous pressure.

Figure 3 shows the front panel of the pulse pressure model. The slide switches select values for the venous return (V.R.), heart rate (H.R.), compliance (C.), and total peripheral resistance (T.P.R.). In addition, two numeric controls specify values for the fraction of the cardiac cycle devoted to systole (systolic fraction) and the integration interval (dt). The two strip-charts display the ventricular ejection rate and arterial pressure. The four digital displays show the current values of the stroke volume, systolic and diastolic pressures, and the amplitude of the pressure pulse. The initial values and constants shown in Figure 3 were taken from Randall.[3]

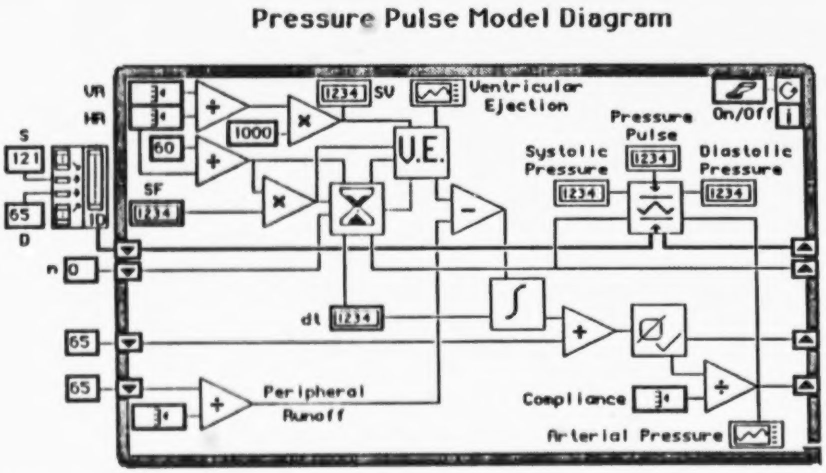

Pressure Pulse Model Diagram
VR
HR
S
121
65
D
60
1000
SV
SF
1234
Ventricular Ejection
V.E.
n
0
dt
Systolic Pressure
Pressure Pulse
Diastolic Pressure
On/Off
65
65
Peripheral Runoff
Compliance
Arterial Pressure

FIGURE 4. Executable diagram of pulse pressure model. The main diagram contains five "virtual instruments" also programmed by the authors: timer (hourglass icon), ventricular ejection (V.E.), integrator (integral sign), error-trapping routine (zero check), and wave analyzer (connected to pressure pulse display). For details, see text.

Figure 4 shows the block diagram for the pressure pulse model. Like the previous model of the cardiovascular system, all the calculations for the model are performed within a While-Wend loop to provide continuous operation and to store current values in shift-registers for use in the subsequent iteration. However, unlike the previous model, the pressure pulse model contains a number of virtual instruments that perform the more complicated program operations, such as timing the cardiac cycle and calculating the rate of ventricular ejection, discussed in detail below.

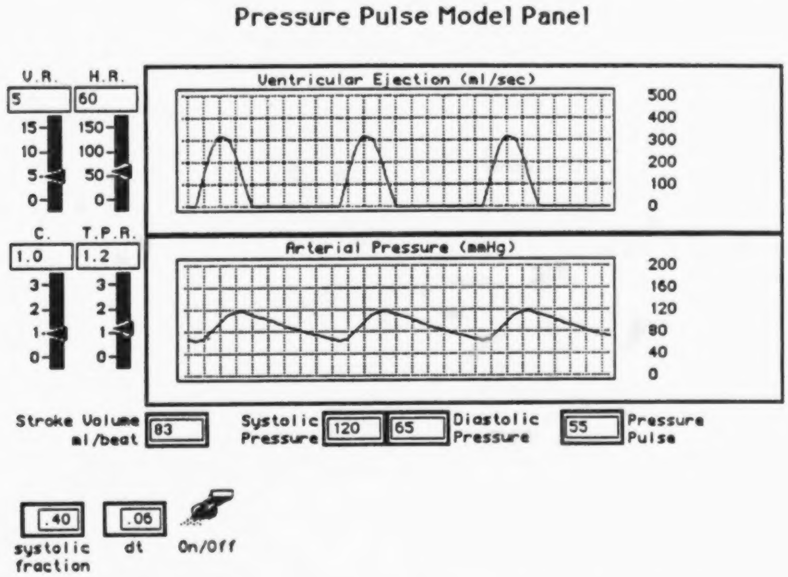

Pressure Pulse Model Panel
V.R.
H.R.
5
60
15
10
5
0
150
100
50
0
Ventricular Ejection (ml/sec)
500
400
300
200
100
0
C.
T.P.R.
1.0
1.2
3
2
1
0
Arterial Pressure (mmHg)
200
160
120
80
40
0
Stroke Volume ml/beat
83
Systolic Pressure
120
65
Diastolic Pressure
55
Pressure Pulse
.40
systolic fraction
.06
dt
On/Off

FIGURE 3. Front panel of pulse pressure model. Slide switches select values for venous return (V.R.), heart rate (H.R.), arterial compliance (C), and total peripheral resistance (T.P.R.). Constants are the systolic fraction of the cardiac cycle and the integration interval (dt). Computed variables are shown on simulated stripcharts or digital displays.

As in the previous model, the program execution proceeds from left to right and starts with the initialization of the shift-registers. The complex icon wired to the top shift-register on the left border is an "array builder." The two numeric constants specifying the initial systolic (S) and diastolic (D) pressures are wired to the left side of the array builder which generates a two-element array that is passed to the shift-register. Note that in LabView, the appearance of a wire depends on the type of data it carries (ie, numeric, array, string, or boolean data) and that the array wire is thicker than the wire used for numeric data. The other three shift-registers are initialized by numeric constants specifying the starting value for the timer (n) and the default values for arterial volume (V) and pressure (P).

Inside the While-Wend loop, using values specified on the front panel for venous return, heart rate, and systolic fraction of the cardiac cycle, the program begins by calculating the stroke volume, the period of the complete cardiac cycle, and the duration of systole. The cardiac period and the duration ofsystole as well as the current values of n and dt are wired to the timer sym-

0742-3233/88/$0.00 + 2.00

bolized by the hourglass icon. The timer is the virtual instrument responsible for the timing of each cardiac cycle and for signaling the beginning and end of systole.

The diagram for the timer is shown in Figure 5. The timer operates by setting n equal to zero at the beginning of each cardiac cycle and incrementing n by one during each iteration until the cardiac cycle is completed. The number of iterations required for a cycle is the cardiac period divided by dt. During each iteration, by using the "greater than, equal to, or less than" function, n is compared to the calculated number of iterations per cycle. The output of this comparator is boolean (true or false) as indicated by the dotted line connecting the "less than" terminal to the case structure selector. So long as n is less than the calculated number of iterations per cycle, the program executes the operations specified in the TRUE form of the case structure, and n is incremented by one. At the end of a cycle, when n is no longer less than the calculated number of iterations per cycle, the FALSE form of the case structure is executed, and n is reset to zero. The time since the beginning of each cycle is simply the product of n multiplied by dt. A second comparator icon is used to compare the elapsed cycle time with the calculated systolic duration and to provide a boolean signal for the beginning and end of systole.

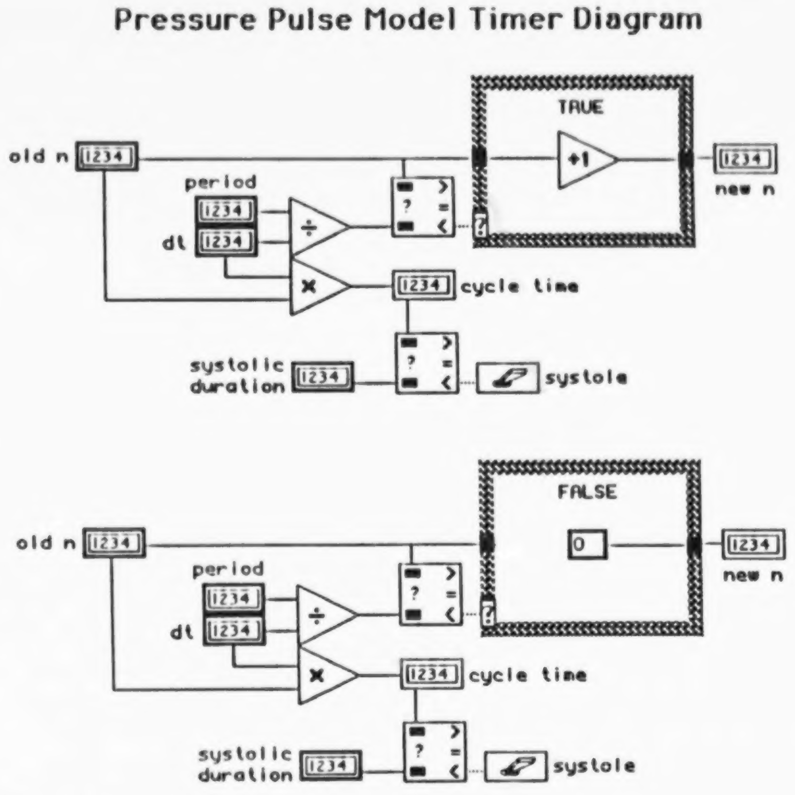


FIGURE 5. Diagram of the virtual instrument "timer." Shown are contents of timer that appears as the hourglass icon in Figure 4. From the period of total cardiac cycle and the integration interval (dt), this instrument calculates the number of iterations per cardiac cycle, computes the time elapsed since the beginning of the current cardiac cycle, and provides a boolean (true-false) signal of whether or not the heart is in systole. Both the true and false forms of the case structure are shown.

The instantaneous rate of ventricular ejection is calculated by the virtual instrument labelled V.E. in Figure 4. The block diagram for the V.E. virtual instrument is shown in Figure 6. From an equation given by Randall,[3] ventricular ejection (VE) is calculated as the positive half of a sine wave:

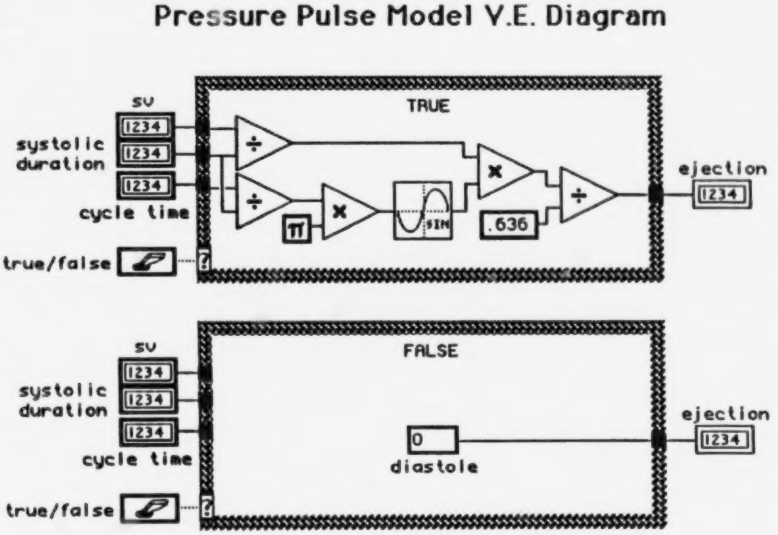
$$VE=(SV/SD) \cdot SIN\ (\pi \cdot time/SD)/0.636$$

Here, SV is the stroke volume, SD is the systolic duration, and time is the time elapsed since the beginning of systole. The constant, 0.636, simply converts the average systolic ejection rate (SV/SD) to its maximum systolic value. In the diagram (Figure 6), this calculation is performed within a TRUE-FALSE case structure. During systole, while the boolean signal from the timer is true, the calculations specified in the TRUE form of the case structure yield the instantaneous ventricular ejection. During diastole, while the boolean signal from the timer is false, the FALSE form of the case structure simply generates a zero for ventricular ejection. The instantaneous volume in the arterial compartment is determined by the difference between ventricular ejection and peripheral runoff. On the first iteration, peripheral runoff is calculated by dividing the initial diastolic pressure (65 mmHg) by the total peripheral resistance set on the front panel slide switch. At the center of the main diagram (Figure 4), peripheral runoff is subtracted from ventricular ejection. The difference between arterial inflow and outflow is multiplied by dt within the virtual instrument symbolized by the homemade integral sign. The result of this integration is the volume increment or decrement that is added to the arterial volume from the previous iteration.

Although it is impossible for an arterial system to have a negative volume, a computer model is under no such restriction. Indeed, depending on the values selected on the front panel, it is quite possible for the present model to develop negative volumes in the arterial compartment or to generate invalid numbers that require the user to restart the program (eg, by dividing by zero). Therefore, the next step in the program is an error checking routine performed by the virtual instrument symbolized by the zero check icon.

Figure 7 shows the diagram for the zero checker. To trap negative or in-

0742-3233/88/$0.00 + 2.00



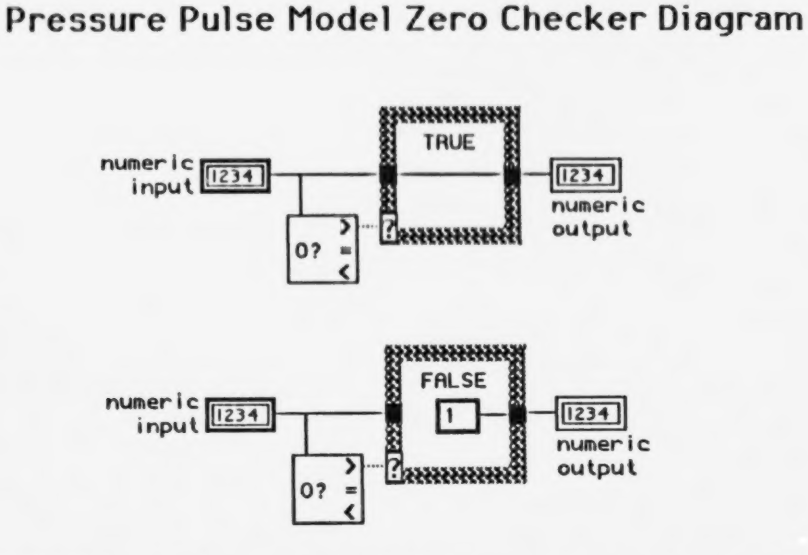
Pressure Pulse Model V.E. Diagram

FIGURE 6. Diagram of the virtual instrument for ventricular ejection. Shown are details of the ventricular ejection calculation symbolized in Figure 4 by the V.E. icon. This instrument generates the positive half of a sine wave during systole (true case) and sets ventricular ejection to zero during diastole (flase case).

valid numbers, the numbers are tested against zero. All numbers greater than zero are passed through the TRUE form of the case structure, whereas numbers less than or equal to zero are reset to one.

After passing through the zero checker, the arterial volume is simply divided by the arterial compliance to determine the instantaneous arterial pressure which is then registered on the stripchart and temporarily stored in the shift-register (lower right border of Figure 4). To determine the systolic and diastolic pressures and the amplitude of the pressure pulse, the instantaneous arterial pressures for each cardiac cycle are accumulated in an array by the virtual instrument symbolized by the wave analyzer icon.

The diagram for the wave analyzer is shown in Figure 8. Recall that the timer sets n equal to zero at the beginning of each cardiac cycle. The wave analyzer consists of a TRUE-FALSE case structure driven by the current value of n. At the beginning of each cardiac cycle (when n equals zero), the array of instantaneous pressures accumulated by the array builder during the previous cycle is processed by the "max-min" function (a menu-available function in LabView) thus retrieving the systolic and diastolic pressures. The amplitude of the pressure pulse is simply the systolic minus the diastolic pressure. The current instantaneous arterial pressure is wired to an empty array builder to become the first element of the new cycle's array which is then passed out of the TRUE form of the case structure to the shift-register on the right border of the While-Wend loop. When n is greater than zero during each subsequent iteration of the cycle, the FALSE form of the case structure uses a single array builder to add each new instantaneous pressure to the accumulating array until n is again set to zero by the timer.



Pressure Pulse Model Zero Checker Diagram

FIGURE 7. Diagram of the zero checker. This is an error-trapping routine that eliminates invalid numbers such as negative arterial volumes and division by zero errors.

EVALUATION

For the life scientist, even one reasonably adept at computer programming, constructing a mathematical model has usually been tedious and time consuming because he had to develop specific routines for data input and output, for approximating nonlinear functions, and for integrating time-dependent variables. Simulations, particularly those on mainframe computers, were generally written in compiled languages that did not have graphics and that often prevented interactive use of the model. Even with the advent of microcomputers, the investigator had to expend more time and effort on supporting software for graphics and interactive utilities than on the model itself. Therefore, when we became aware of LabView, our hope was that a graphic programming language would make modeling more intuitive and much easier

0742-3233/88/$0.00 + 2.00

for the life scientist than it had been in the past.

In evaluating LabView, we used several criteria. First, we felt that the user should only have to build his model, not develop graphics or interactive routines. Second, the user should be able to run the simulation continuously and obtain results in a readily comprehensible form such as strip-charts or X-Y plots. Third, the simulation should be executed in an acceptable amount of time. Fourth, the model should be interactive to the extent that the modeler can easily interrupt the simulation to change a variable's value and resume the simulation. Similarly, altering the model itself and beginning a new simulation should be simple and straight forward. Finally, the simulation language should have all the arithmetic, transcendental, and matrix math routines that high-level languages usually offer. LabView satisfies many of these criteria.

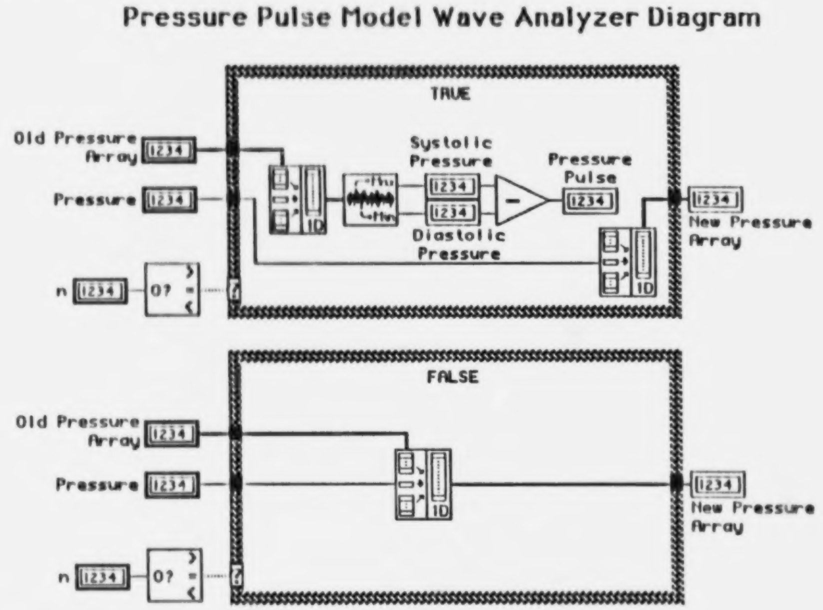

Pressure Pulse Model Wave Analyzer Diagram

FIGURE 8. Diagram of wave analyzer. At the beginning of each cardiac cycle (true case), this instrument uses the "min-max" function to select the diastolic and systolic pressures from an array of pressure values stored during the previous cardiac cycle (false case).

Programming Environment

The metaphor of a virtual instrument, with controls and indicators on a front panel and an executable block diagram, is a concept readily appreciated by most physiologists. Indeed, the ease of presenting both input and output data in graphic, easily assimilated forms is perhaps the best feature of LabView. In fact, largely because of LabView's virtual instrument approach to programming, it was surprisingly easy to exploit LabView's ability to display data graphically and to implement the two models we described. Starting from a short list of values for constants and the inputs and outputs needed for the front panel, only three hours of programming were required to create an operational version of the simple cardiovascular model. To develop a similar model in BASIC with the same capabilities for user interaction and the same high quality graphics would have required much more time and programming expertise.

Front Panel

Although the two models we presented make limited use of the many available front panel controls and indicators, it should be noted that all of the controls and indicators in LabView are menu-selected with specified ranges and scales that can easily be changed by the user (though not while a program is running). Range checking is done automatically, and out-of-range errors can be ignored, coerced within the specified range, or allowed to stop the program (as determined by the user). Positioning and changing the size of the controls and indicators to acheive a particular layout on the front panel are relatively simple operations that require some familiarity with the Macintosh mouse. However, there is no provision for customizing controls or indicators or for adding additional graphics to the front panel (eg, it is not possible to add a schematic illustration of a model to the front panel).

Block Diagram

The block diagram is analogous to the program code in other high-level languages. In a small program such as the simple cardiovascular model (Figure 2), the diagram is truly self-explanatory except for one or two LabView idiosyncrasies like the shift-registers (the only way to use variable values recursively). However, even slightly more complicated programs like the pulse pressure model (Figure 4) can be difficult to decipher and debug. Their indecipherability stems partly from the inclusion of virtual instruments within the main block diagram. The block diagrams of such instruments within instruments cannot be viewed at the same time that the overall diagram is examined. Futhermore, case structures and other program control devices are symbolized by several layers of figures, only one of which can be viewed on the screen at a time.

Constructing a comprehensible LabView block diagram requires a sense of spatial organization and some artistry. In LabView block diagrams, data flow occurs most naturally from left to right because the input terminals of function icons are on their left, and their outputs are on the right. The orientation of the icons cannot be changed. A further constraint is the small size of the Mac Plus screen. Therefore, some forethought is necessary to anticipate the overall layout of the diagram and the amount of space that the various function icons will occupy on the screen.

Failing to plan ahead inevitably leads to sphagetti-like tangles of wire that cannot easily be debugged. Even worse, editing such poorly planned diagrams requires completely "un-wiring" the entire diagram just to make a few simple changes.

In LabView block diagrams, four different types of data are depicted by wires with different appearances. Fortunately, LabView does not make the programmer specify the type he needs but instead makes the appropriate selection automatically depending, for example, on whether the selected function requires a simple variable or an array. Logical errors and connections between inappropriate devices are immediately indicated by "broken wires," an error message that often fails to pinpoint the problem.

Execution Speed

We have not quantified the execution speed of LabView, but our impression is that it runs at about the same speed as an interpreted BASIC. Thus, execution speed is a potential problem. On the Mac Plus, the pulse pressure model executed at an acceptable rate, but each iteration produced a perceptible jitter as the strip-chart simulator scrolled across the monitor. By contrast, on the faster Macintosh II, the arterial waveform glided smoothly across the screen "like the pulse of a perfect heart." Therefore, to maintain acceptable speed with larger models than those presented here, it may be necessary to run the simulations on a Macintosh II. Alternatively, the program could be compiled. The manufacturer claims to have a complier for LabView, although it is not yet available commercially.

Conclusions

Before using it, we had the impression that LabView would make mathematical modeling possible for all life scientists who are not computer programmers. In most respects, LabView lived up to this expectation, but to some extent it did not. Certainly, the many useful features of LabView, such as the math routines and the graphic displays, can easily be used by the unsophisticated programmer. Similarly, simple diagrams are indeed self-explanatory programs. In our opinion, an inexperienced programmer could construct a much more sophisticated model in LabView than in other high-level languages. However, more elaborate LabView programs can be as difficult to decipher and debug as those in other languages. Similarly, like other computer languages, LabView can demand arcane programming tricks, and the methods that have to be used to store variable values and to branch on a particular condition are often not straightforward. Nevertheless, even the accomplished programmer will find much to admire and use in LabView: arithmetic and logical functions, array arithmetic, matrix and vector algebra, complex numbers, statistical functions, and signal processing routines including fast Fourier transforms. All of these routines appear as simple icons that naive and sophisticated programmers alike can easily incorporate into their models. Therefore, considering these and the previously mentioned advantages of LabView, we recommend that LabView be seriously considered as a novel modeling methodology with the potential of enabling the average life scientist to simulate complex biological systems.

To obtain a copy of the LabView programs presented here, send the authors an 800k, 3.5 inch disk and an appropriate, stamped, self-addressed mailing container.

This work was supported by USPHS grants HL-36080 and AM-33024.

REFERENCES

1. Coleman, TG, and FR Sias. Simulation of biological systems. DECUS. Digital Equipment Corp., Maynard, MA, 1969, pp.1-18.
2. Guyton, AC, AW Lindsey, and BN Kaufman. Effect of mean circulatory filling pressure and other peripheral circulatory factors on cardiac output. Amer. J. Physiol. 180:463-468, 1955.
3. Randall, JE. Microcomputers and physiological simulation, second ed., Raven Press, New York, NY, 1987, pp.207-219.
4. Rothe, CF. A computer model of the cardiovascular system for effective learning. The Physiology Teacher 22: 29-33, 1979.
5. Vose, GM and G Williams. LabView: laboratory virtual instrument engineering workbench. Byte 11(9):84-92, 1986.
6. Wolfe, R. Block diagrams and icons alleviate the customary pain of programming GPIB systems. Electronic Design 34:125-132, 1986.

SUBSCRIPTION INFORMATION

Computers in Life Science Education is published monthly by National Resource for Computers in Life Science Education, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Subscription rate is $30.00 for 12 issues, including postage and handling in the United States and Canada. Add $20.00 for postage (airmail) in Mexico and Europe and $23.00 for the rest of the world.

This newsletter has been registered with the Copyright Clearance Center, Inc. Consent is given for copying of articles for personal or internal use, or for the personal or internal use of specific clients. This consent is given on the condition that the copier pay through the Center the per-copy fee stated in the code on the first page for copying beyond that permitted by the US Copyright Law. If no code appears on an article, the author has not given broad consent to copy and permission to copy must be obtained directly from the author. This consent does not extend to other kinds of copying, such as for general distribution, resale, advertising and promotional purposes, or for creating new collective works.

Address orders, changes of address, and claims for missing issues to NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Claims for missing issues can be honored only up to three months for domestic addresses and six months for foreign addresses. Duplicate copies will not be sent to replace ones undelivered due to failure to notify NRCLSE of change of address.

Address editorial correspondence to Harold I. Modell, PhD, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. (BITNET MODELL@UWALOCKE)

POSTMASTER: Send address changes to *Computers in Life Science Education*, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

0742-3233/88/$0.00 + 2.00

VOLUME 5 NUMBER 8, AUGUST 1988
CLSEE3 5(8)57-64, 1988 ISSN 0742-3233

COMPUTERS
IN LIFE
SCIENCE
EDUCATION

HAROLD I. MODELL
Department of Radiology
University of Washington
Seattle, Washington

MARCEL BLANCHAER
Department of Biochemistry
Faculty of Medicine
University of Manitoba
Winnipeg, Manitoba

THEODORE J. CROVELLO
Graduate Studies and Research
California State University, Los Angeles
Los Angeles, California

JAMES W. ECKBLAD
Department of Biology
Luther College
Decorah, Iowa

TSEGAYE HABTEMARIAM
School of Veterinary Medicine
Tuskegee University
Tuskegee, Alabama

DONNA LARSON
School of Nursing
Grand Valley State College
Allendale, Michigan

TERRY M. MIKITEN
Graduate School of Biomedical Sciences
University of Texas Health Science Center
San Antonio, Texas

JAMES E. RANDALL
Department of Physiology
Indiana University
Bloomington, Indiana

PATRICIA SCHWIRIAN
College of Nursing
Ohio State University
Columbus, Ohio

RICHARD STULL
College of Pharmacy
University of Arkansas
Little Rock, Arkansas

JAMES W. WOODS
Lister Hill National Center
for Biomedical Communications
National Library of Medicine
Bethesda, Maryland

DOROTHY WOOLEY-McKAY
Department of Biology
Glendale Community College
Glendale, Arizona

GLEN YOSHIDA
Department of Life Sciences
Los Angeles Southwest College
Los Angeles, California

NRCLSE

CONTENTS

USE OF A COMPUTER SIMULATION TO REINFORCE WET LABS IN NUCLEAR MEDICINE 57
Harold I. Modell and Michael M. Graham

THE BULLETIN BOARD 61

CAN YOU HELP? 63

USE OF A COMPUTER SIMULATION TO REINFORCE WET LABS IN NUCLEAR MEDICINE

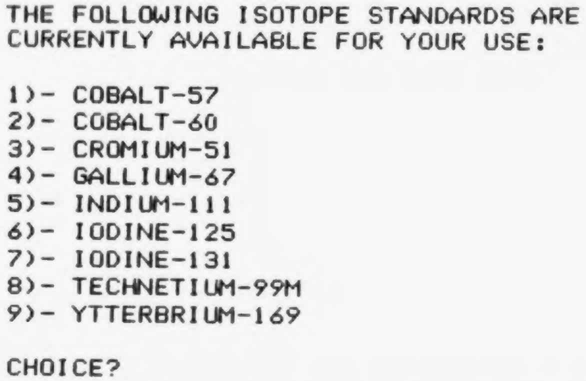
Harold I. Modell and Michael M. Graham
Department of Radiology, University of Washington, Seattle, Washington

Many procedures commonly encountered in Nuclear Medicine are indicator dilution determinations. A known quantity of a radionuclide, for example, is introduced into an unknown volume. By comparing the activity within an aliquot of the unknown to that of a standard, the unknown volume can be calculated. The samples are generally counted in a well counter. If these determinations are to be carried out accurately and interpreted properly, it is essential that Nuclear Medicine technologists and physicians understand the conservation of mass principles underlying indicator dilution techniques as well as the errors that can arise as a result of well counter characteristics. The American Board of Nuclear Medicine recommends that all resident training programs include principles and limitations of both indicator dilution techniques and well counters.

In our resident program, these issues have been addressed through a series of laboratory exercises conducted once each year. To ensure that the lab sessions do not interfere with Nuclear

0742-3233/88/$0.00 + 2.00

Medicine clinic activities, a finite time commitment must be made to deal with various logistical problems related to equipment, space, and scheduling. Although some residents wish to explore these topics further during the remainder of the year, they have been unable to do so because of time and space constraints. To overcome this limitation, we have developed a simulation of a well counter, designed for use currently with Apple II computers, that allows the user to explore indicator dilution principles and the effects of counter characteristics on counting efficiency.



```
THE FOLLOWING ISOTOPE STANDARDS ARE
CURRENTLY AVAILABLE FOR YOUR USE:

1)- COBALT-57
2)- COBALT-60
3)- CROMIUM-51
4)- GALLIUM-67
5)- INDIUM-111
6)- IODINE-125
7)- IODINE-131
8)- TECHNETIUM-99M
9)- YTTERBRIUM-169

CHOICE?
```

FIGURE 1. Initial screen of well counter simulation listing the isotopes that can be counted.

WELL COUNTER DESIGN

The "standard" well counter currently used in Nuclear Medicine environments consists of a sodium idodide (NaI) crystal with a hole in it, a photomultiplier tube, a high voltage source, an amplifier, and a multi-channel analyzer. The gamma rays from a sample in the hole interact with the crystal, causing flashs of light. The brightness of each flash of light is proportional to the energy of the gamma ray. The light is sensed by the photomultiplier tube resulting in a small electrical pulse that is propotional to the brightness of the flash of light. The small pulse is amplified and sent to the multi-channel analyzer, which, along with its electronics, displays the data.

Counts obtained with the NaI crystal well counter are subject to a variety of factors. Some of these are related to the NaI crystal and to the electronics processing the detected events, some depend on the sample size and the geometry of the counting system, and others are dependent upon the random nature of radioactive disintegrations. The counting efficiency reflects the interaction of these factors. To gain meaningful information when using such an instrument, it is necessary to understand the factors contributing to the counting efficiency.

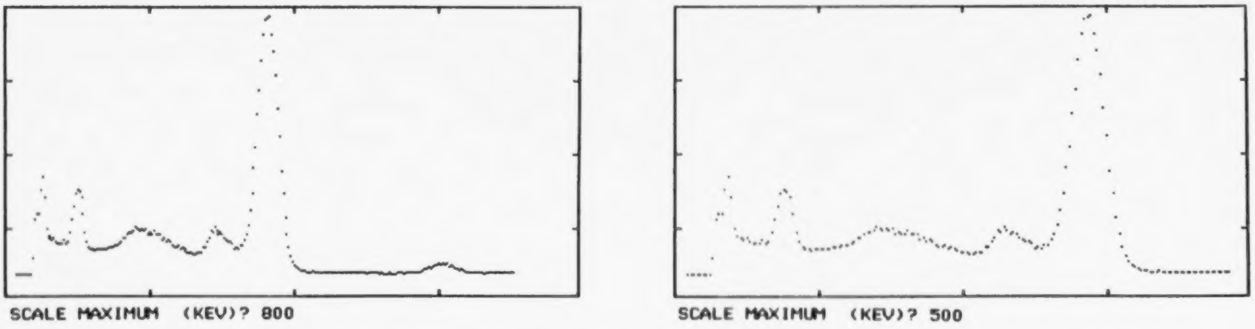
The wet labs in our curriculum are designed to help the residents examine a number of these factors including position of the sample within the detector chamber, sample volume, influence of the container in which the sample is placed, and setting the counting window.

WELL COUNTER SIMULATION

The well counter simulation provides a means by which students can extend their wet lab experience to further explore indicator dilution principles and the effects of counter characteristics on counting efficiency. Dead time losses and Poisson statistics are incorporated into the counting scheme. Counting characteristics of the simulated counter were drawn from data described by Hine[1] and Sorenson and Phelps.[2]

Setting up the counter

When using the simulation, the student is presented first with a list of standards, shown in Figure 1, that are available for setting the counting window. The digitized energy spectrum



```
SCALE MAXIMUM (KEV)? 800
```

```
SCALE MAXIMUM (KEV)? 500
```

FIGURE 2. Energy spectra for Iodine-131. In the *left panel,* the student has chosen 800 Kev as the scale limit. In the *right panel,* the spectrum is shown with 500 Kev as the scale limit. The process can be repeated as many times as desired.

for each of the standards is stored in a separate file and accessed by the program as needed. After choosing the desired standard, the student is presented with an energy scale on which the energy spectrum of the chosen standard will be displayed. The student can adjust the energy scale (Figure 2) to best display the spectrum for setting the desired counting window.

The counting window is then set by using the arrow keys to move a hairline to the desired positions on the spectrum (Figure 3). If the chosen window is unsatisfactory, it can be reset.

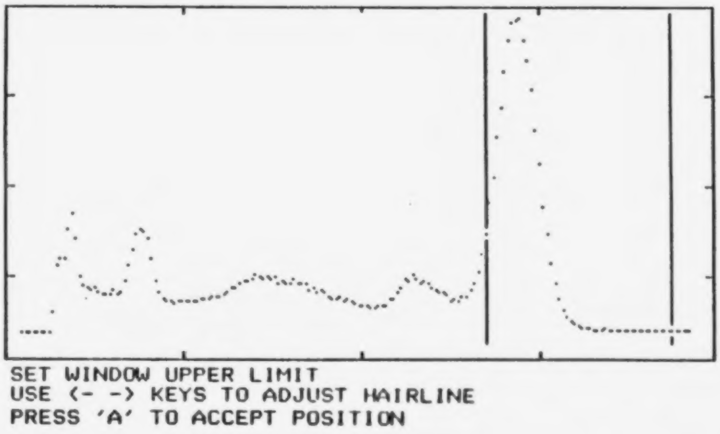

```
SET WINDOW UPPER LIMIT
USE <- -> KEYS TO ADJUST HAIRLINE
PRESS 'A' TO ACCEPT POSITION
```

FIGURE 3. Spectrum of Iodine-131 with hairlines indicating the energy limits chosen for the counting window. The lower limit has been defined.

Sample preparation
Having defined the counter set-up, the student must prepare a sample to count (Figure 4). In doing so, the amount of isotope to be used as the indicator and the volume in which it is to be diluted are defined. At this point, a message is presented reminding the student that the basic underlying assumption in all indicator dilution determinations is that the volume in which the indicator resides is well mixed.

The next step is to define the sample volume that is to be put into the counter and define the counting time.

Counter data
When sample preparation is complete, and counting parameters have been defined, the program reviews the sample definition and counter parameters and presents the results of the counting process (Figure 5). This screen also contains information about the counting efficiency. It presents the apparent counting efficiency (total counts detected relative to the total theoretical counts that should have been detected) as well as the actual overall efficiency (apparent counting efficiency corrected for background).

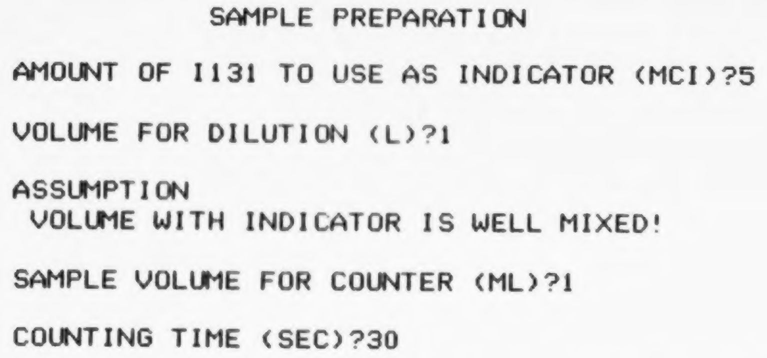

```
SAMPLE PREPARATION

AMOUNT OF I131 TO USE AS INDICATOR (MCI)?5

VOLUME FOR DILUTION (L)?1

ASSUMPTION
 VOLUME WITH INDICATOR IS WELL MIXED!

SAMPLE VOLUME FOR COUNTER (ML)?1

COUNTING TIME (SEC)?30
```

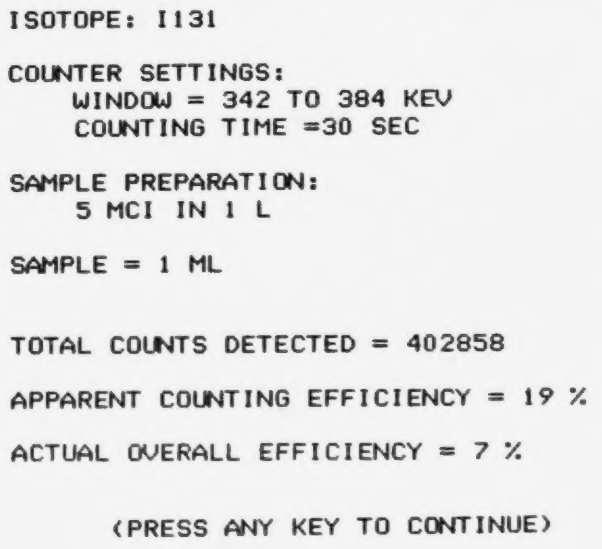
FIGURE 4. Interactive screen on which the student has defined how the sample is to be prepared.

Options
After the counting data have been presented, the student is presented with an options menu (Figure 6) that allows redefinition of the tracer, counter parameters, and sample parameters. At this point, the choice to count the same sample again is also provided. In this way, the random variation in counts seen with actual well counters can be examined. For example, Table 1 lists the counts recorded when the same sample of Iodine-131 was counted five times.

Error messages
Error messages presented to the student are designed to promote an additional learning experience by providing additional information relevant to the error. In some cases, the error relates to a specific choice made by the student. For example, if the student choses to count the sample for less than 10 seconds, a message is presented indicating that a longer count time will provide better statistical data. In other cases, the error results from the counter characteristics or from a combination of choices. For example, if the count rate from the sample is too high for the counter, a message appears indicating that the counter is paralyzed.

MODEL SOLUTION
Data used for incorporating the effects of the various counting factors such as the effects of counter deadtime and sample size were obtained from chapters on well counters presented by Hine[1] and Sorenson and Phelps[2]. Sev-

0742-3233/88/$0.00 + 2.00



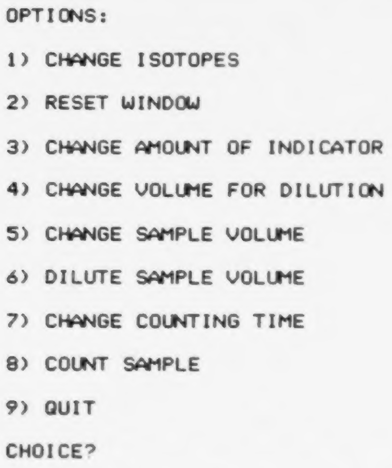
```
ISOTOPE: I131

COUNTER SETTINGS:
    WINDOW = 342 TO 384 KEV
    COUNTING TIME =30 SEC

SAMPLE PREPARATION:
    5 MCI  IN 1 L

SAMPLE = 1 ML


TOTAL COUNTS DETECTED = 402858

APPARENT COUNTING EFFICIENCY = 19 %

ACTUAL OVERALL EFFICIENCY = 7 %


       (PRESS ANY KEY TO CONTINUE)
```

FIGURE 5. Output showing the results of the well counter count.

Table 1. Counts obtained from repeated counting trials of sample described in Figure 4.

Trial	Counts detected
1	403,070
2	402,228
3	402,567
4	402,905
5	403,205

eral factors enter in to calculating the counts detected for a given sample. Initially, the actual activity (mCi) per ml of sample is calculated. Using this value, the theoretical counts/sec for each ml of sample are calculated according to the following equation.



```
OPTIONS:

1) CHANGE ISOTOPES

2) RESET WINDOW

3) CHANGE AMOUNT OF INDICATOR

4) CHANGE VOLUME FOR DILUTION

5) CHANGE SAMPLE VOLUME

6) DILUTE SAMPLE VOLUME

7) CHANGE COUNTING TIME

8) COUNT SAMPLE

9) QUIT

CHOICE?
```

FIGURE 6. Options menu from well counter program.

Counts/sec = mCi x (3.7 x 10^7 disintegrations/sec) x Counting efficiency of the isotope

To obtain the counting efficiency of each isotope, the gamma ray efficiency/disintegration is multiplied by the quantum detection efficiency for each gamma ray produced by the isotope. The resultant values are then summed to obtain the counting efficiency.[1]

The value obtained for counts/sec is then adjusted for the sample volume if the sample volume is greater than 1 ml and for samples that have been diluted.[1]

The influence of deadtime is then incorporated into the calculation according to Sorenson and Phelps.[2]

Background activity, calculated as .35 counts/sec per Kev in the counting window, is the next factor added to the counts detected.

The total counts reported are calculated from the following equation.

Total counts = ((counts/sec x % spectrum that represents the counting window) + backgound) x total counting time.

This value is then adjusted by adding a random gaussian variation to it.

The total theoretical counts that should have been detected (used to present the actual overall efficiency to the student) is calculated from the actual activity per ml of sample, the definition of a mCi of activity, the counting time, the fraction of the energy spectrum within the counting window, and the sample size being counted.

EVALUATION

A systematic evaluation of the effectiveness of this program has been difficult to perform because the number of new residents exposed to the material each year is very small, normally less than five, and the program is available on an optional basis. Nevertheless, residents who have used the program have indicated that they have found it helpful in reinforcing the material presented in the wet labs.

REFERENCES

1. Hine, GJ. γ-Ray sample counting. In: Hine, GJ ed. Instrumentation in Nuclear Medicine. New York, Academic Press, 1967, p. 275-291.
2. Sorenson, JA and ME Phelps. Physics in Nuclear Medicine. New York, Grune & Stratton, 1980.

0742-3233/88/$0.00 + 2.00

THE BULLETIN BOARD

The Bulletin Board is published periodically to inform readers of upcoming meetings of interest. If you know of meetings, symposia, continuing education courses, etc, of interest to life science educators, and they do not appear in The Bulletin Board, please let us know. Send pertinent information to: Dr. Harold Modell, NRCLSE, RC-70, University of Washington, Seattle, WA 98195, or let us know via BITnet. NRCLSE's BITnet address is: MODELL@UWALOCKE

AUGUST 24-26, 1988. 10th Annual Conference. Interactive Videodisc in Education and Training. Washington, D.C.

Contact:

Society for Applied Learning Technology
50 Culpeper Street
Warrenton, VA 22816
(800) 457-6812
In VA: (703) 347-0055

OCTOBER 6-8, 1988. Health Care 1988: The Challenge of Change Morgantown, West Virginia.

Contact:

Janet Wang
School of Nursing
West Virginia University
Morgantown, WV 26506
(304) 293-4297.

OCTOBER 14-15, 1988. Fall, 1988 Semi-Annual Meeting. Association of Biologists for Computing. San Jose, California.

Contact:

Charles W. Bell, President
Association of Biologists for Computing
Department of Biological Sciences
San Jose State University
San Jose, CA 95192

NOVEMBER 6-9, 1988. The 12th Annual Symposium on Computer Applications in Medical Care (SCAMC). Washington, D.C.

Contact:

Robert A. Greenes, MD
Program Chair
SCAMC – Office of CME
The George Washington University Medical Center
2300 K Street, NW
Washington, D.C. 20037
(202) 994-8928

NOVEMBER 7-10, 1988. Association for the Development of Computer- Based Instructional Systems (ADCIS) 30th International Conference. Philadelphia, Pennsylvania.

Contact:

ADCIS, 409 Miller Hall
Western Washington University
Bellingham, WA 98225
(206) 676-2860

NOVEMBER 10-11, 1988. First Annual Meeting. Medical Interactive Video Consortium. Washington, D.C.

Contact:

J. Henderson, MD, MIVC
Uniformed Services University of the Health Sciences
4301 Jones Bridge Road
Bethesda, MD 20814-4799

JANUARY 30 - FEBRUARY 2, 1989. 1989 Florida Instructional Computing Conference. Orlando, Florida.

Contact:

Florida Department of Education
Office of Educational Technology
Knott Building
Tallahassee, FL 32399
(904) 488-0980

MAY 15-19, 1989. Medical Informatics and Education: An International Symposium. Victoria, B.C., Canada.

Contact:

Conference Services
Division of University Extension and Community Relations
University of Victoria
P.O. Box 1700
Victoria, B.C. V8W 2Y2
Canada
(604) 721-8475

OCTOBER 16-20, 1989. MEDINFO 89. The Sixth World Congress on Medical Informatics. Beijing, China.

Contact:

Phil R. Manning, MD
Chairman, Scientific Program Committee
MEDINFO 89
USC School of Medicine
1975 Zonal Avenue, KAM 317
Los Angeles, CA 90033
(213) 342-9370

Gao Pengyuan, MD or Ms Shan Huiqin
China Medical Informatics Association
MEDINFO 89 Secretariat
55 Xueyuan Nanlu, Wei Gong Cun
Haidian District, PO Box 8139
Beijing, China 100081

0742-3233/88/$0.00 + 2.00

APPLE II? IBM-PC? MACINTOSH? ... NO PROBLEM!

SIMULATIONS IN PHYSIOLOGY

– The Respiratory System –

Harold I. Modell, Ph.D.
School of Medicine, University of Washington, Seattle,

- **Series of 12 Simulations in Respiratory Physiology**
- **117 Page Laboratory Manual**
- **Designed for use in student laboratory and group discussion environments**
- ***Pictorial* outputs designed to provide conceptual aid, show where variable values are measured, or illustrate the model and how it is solved**
- ***Tabular* outputs allow comparison of data from up to 7 'experiments'**
- **Available for Apple II, IBM-PC (MS-DOS) compatible, and Macintosh (requires Microsoft BASIC) computers**
- **Purchase includes permission to make enough copies to supply appropriate student populations**

ORDERING INFORMATION

Computer Programs*
12 Simulations written in BASIC
Documentation
One copy of student laboratory manual
. . . . $100

*IBM-PC version uses CGA graphics
Macintosh version requires Microsoft BASIC

Student Laboratory Manuals

Quantities of 1-25	. . . . $10 each
Additional copies	. . . . $8.50 each

Address orders to:
NRCLSE
Mail Stop RC-70
University of Washington
Seattle, WA 98195

Be sure to indicate which version you need!

PROGRAM OVERVIEW

Title	Material covered
MECHANICS	
Static Relationships	Elastic properties of the lung, chest wall, and total respiratory system
Dynamic Relationships I	Effects of lung compliance and airway resistance on tidal volume development
Work of Breathing	Oxygen cost of elastic, resistive, and total work during inspiration
Dynamic Relationships II	Respiratory dynamics of the total respiratory system
GENERAL GAS EXCHANGE	
Alveolar Gas Exchange	Gas exchange between the atmosphere and alveolar reservoir
O_2 and CO_2 Dissociation Curves	Interrelationships between the O_2 and CO_2 dissociation curves
Exchange from Atmosphere to Tissues	Influence of alveolar ventilation, cardiac output, and anatomic shunt flow on arterial blood composition and gas exchange at the tissues
Chemoregulation of Respiration	Influence of chemoreceptor sensitivity and respiratory mechanics on O_2 and CO_2 response curves
V_A/Q RELATIONSHIPS	
Gas Exchange in a Single Alveolus	Effects of ventilation-perfusion ratio and inspired gas composition on exchange in a single exchange unit
The Non-Uniform Lung	Gas exchange from atmosphere to tissues with V_A/Q mismatching in the lung
Overall Gas Exchange	Gas exchange from atmosphere to tissues with V_A/Q mismatching and a true shunt
ACID-BASE BALANCE	
Acid-Base Balance: Fundamental Relationships	Acid-Base balance from a Base Excess viewpoint

CAN YOU HELP?

Among the major goals of NRCLSE are to help life science educators identify colleagues who share a common interest in the use of the computer as an educational tool (see Annual Colleague Directory, February - April, 1988 CLSE) and to help life science educators identify appropriate software for use in their curricula.

In an attempt to achieve the latter, we routinely publish software lists (see Where's the Software, May - June, 1988 CLSE). However, these lists do not offer any information regarding the applicability of programs to specific curricular needs. To provide this type of information, *we need your help*. Please take a few moments to let us know *what software works for you*. Providing information in the format presented below will help us to organize this information to share with colleagues.

Mail information to NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. ***Please include your name, address, phone nubmer, and BITnet address (if applicable) with your response.***

SOFTWARE INFORMATION REPORT

Name of software:

Source of software:

Type of program:

Tutorial (Q & A) **Simulation** **Combination**

Equipment needed to run progam:

Apple II **IBM-PC** **Macintosh** **Mainframe** **Other**

Student population using software:

Undergraduate **Graduate** **Medical/Veterinary** **Dental** **Nursing**

Content area covered by this software:

How do you use this software:

Independent study **Classroom instruction** **Student laboratory**

Would you be willing to discuss your use of this program with colleagues?

Yes **No**

What do you like *best* about this software?

What do you like *least* about this software?

0742-3233/88/$0.00 + 2.00

AIMS AND SCOPE

The goal of *Computers in Life Science Education* is to provide a means of communication among life science educators who anticipate or are currently employing the computer as an educational tool. The range of content includes, but is not limited to, articles focusing on computer applications and their underlying philosophy, reports on faculty/student experiences with computers in teaching environments, and software/hardware reviews in both basic science and clinical education settings.

INVITATION TO CONTRIBUTORS

Articles consistent with the goals of *Computers in Life Science Education* are invited for possible publication in the newsletter.

PREPARATION AND SUBMISSION OF MATERIAL

Articles submitted for publication should not exceed 2000 words and should be typewritten, double spaced, with wide margins. The original and two copies including two sets of figures and tables should be sent to the Editor: Dr. Harold Modell, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

Title page should include full title, list of authors, academic or professional affiliations, and complete address and phone number of the corresponding author.

Illustrations should be submitted as original drawings in India ink or sharp, unmounted photographs on glossy paper. The lettering should be such that it can be legible after reduction (width of one column = 5.7 cm).

Reference style and form should follow the "number system with references alphabetized" described in the Council of Biology Editors Style Manual. References should be listed in alphabetical order by the first author's last name, numbered consecutively, and cited in the text by these numbers.

RESPONSIBILITY AND COPYRIGHT

Authors are responsible for accuracy of statements and opinions expressed in articles. All authors submitting manuscripts will be sent a copyright transfer form to complete. The completed form must be returned before the work will be published.

SUBSCRIPTION INFORMATION

Computers in Life Science Education is published monthly by National Resource for Computers in Life Science Education, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Subscription rate is $30.00 for 12 issues, including postage and handling in the United States and Canada. Add $20.00 for postage (airmail) in Mexico and Europe and $23.00 for the rest of the world.

This newsletter has been registered with the Copyright Clearance Center, Inc. Consent is given for copying of articles for personal or internal use, or for the personal or internal use of specific clients. This consent is given on the condition that the copier pay through the Center the per-copy fee stated in the code on the first page for copying beyond that permitted by the US Copyright Law. If no code appears on an article, the author has not given broad consent to copy and permission to copy must be obtained directly from the author. This consent does not extend to other kinds of copying, such as for general distribution, resale, advertising and promotional purposes, or for creating new collective works.

Address orders, changes of address, and claims for missing issues to NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Claims for missing issues can be honored only up to three months for domestic addresses and six months for foreign addresses. Duplicate copies will not be sent to replace ones undelivered due to failure to notify NRCLSE of change of address.

Address editorial correspondence to Harold I. Modell, PhD, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. (BITNET MODELL@UWALOCKE)

POSTMASTER: Send address changes to *Computers in Life Science Education*, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

0742-3233/88/$0.00 + 2.00

VOLUME 5 NUMBER 9, SEPTEMBER 1988

CLSEE3 5(9), 65-72, 1988 ISSN 0742-3233

COMPUTERS IN LIFE SCIENCE EDUCATION

HAROLD I. MODELL
Department of Radiology
University of Washington
Seattle, Washington

MARCEL BLANCHAER
Department of Biochemistry
Faculty of Medicine
University of Manitoba
Winnipeg, Manitoba

THEODORE J. CROVELLO
Graduate Studies and Research
California State University, Los Angeles
Los Angeles, California

JAMES W. ECKBLAD
Department of Biology
Luther College
Decorah, Iowa

TSEGAYE HABTEMARIAM
School of Veterinary Medicine
Tuskegee University
Tuskegee, Alabama

DONNA LARSON
School of Nursing
Grand Valley State College
Allendale, Michigan

TERRY M. MIKITEN
Graduate School of Biomedical Sciences
University of Texas Health Science Center
San Antonio, Texas

JAMES E. RANDALL
Department of Physiology
Indiana University
Bloomington, Indiana

PATRICIA SCHWIRIAN
College of Nursing
Ohio State University
Columbus, Ohio

RICHARD STULL
College of Pharmacy
University of Arkansas
Little Rock, Arkansas

JAMES W. WOODS
Lister Hill National Center
for Biomedical Communications
National Library of Medicine
Bethesda, Maryland

DOROTHY WOOLEY-McKAY
Department of Biology
Glendale Community College
Glendale, Arizona

GLEN YOSHIDA
Department of Life Sciences
Los Angeles Southwest College
Los Angeles, California

NRCLSE

CONTENTS

USING *STELLA* SIMULATION SOFTWARE IN LIFE SCIENCE EDUCATION 65
Thomas G. Coon

USING *STELLA* SIMULATION SOFTWARE IN LIFE SCIENCE EDUCATION

Thomas G. Coon
School of Forestry, Fisheries and Wildlife, University of Missouri, Columbia, Missouri

Mathematical modeling has a rich potential for use in teaching the life sciences. While traditional approaches may emphasize memorization of structures and functions, simulation allows a student to develop his or her understanding and analysis of living systems by testing hypotheses about how the systems work. In the past, simulation has been unapproachable in other than advanced undergraduate or graduate level courses, mainly for logistical reasons. The use of modeling in teaching is dependent on students 1) having access to computer facilities adequate to handle many iterative calculations and large data sets and 2) being facile programmers. Before the development of personal computers with large memory and high speed, students were limited to the use of mainframe computers and standard multi-purpose programming languages such as FORTRAN. While the newer personal computers have sufficient speed and memory to serve even the sloppiest of modelers, they did not eliminate the need for students to be programmers before becoming modelers. It was nearly inevitable that a simulation class would devolve into a

EDITOR'S NOTE

Due to space limitations, **Keeping Abreast of the Literature,** CLSE's regular quarterly feature due to appear in this issue will appear in next month's issue.

0742-3233/88/$0.00 + 2.00

programming class; the students would develop their programming skills, but rarely to the level at which they could use those skills to build, test and use their own models.

Several solutions have developed to alleviate the need for students in biological modeling to be expert programmers. One solution is custom-made software packages that are programmed to run simulations on particular subjects, such as those described by Eckblad.[1] Another, more general solution is a programming language designed for modeling that students can learn and use on personal computers. One package designed to meet this need is STELLA, developed by Barry Richmond and others at High Performance Systems, Inc.[3] STELLA was designed by Richmond et al[4] to make modeling available as a learning tool for students of all disciplines. The name STELLA is an acronym for Structural Thinking, Experiential Learning Laboratory with Animation, a cumbersome explication that is less prominently expressed in later versions of the user's guide. The creators of this software state that their motivation for developing STELLA was to make the discovery approach to any discipline of study more accessible and more fruitful.. Although this article does not address all disciplines, STELLA is a resounding success for teaching the dynamic aspects of the life sciences. It is important to keep in mind that the reason for using modeling as a teaching tool is not to make it easier for students to make predictions about the outcome of life processes, but to make it possible for students to develop their understanding of life processes. Students can effectively accomplish this goal if they are challenged to 1) state their understanding of the dynamics of a living system in a structured format (ie, a model), and 2) test their understanding by asking questions of their model using a structured, experimental procedure. STELLA allows students to carry out both of these steps.

STELLA is designed to operate on Macintosh computers (512K memory or greater), and it takes full advantage of the distinctive Macintosh user interface. It allows a user to begin with a conceptual model of a system and move through the standard steps of model building and testing until the model is ready to use as an experimental instrument of study. It reinforces the standard modeling process of building a conceptual model, making the model quantitative, validating the model, and then using the model as a study tool.[2] Furthermore, it keeps the user honest in that the model will not work unless every parameter is defined and connected to the rest of the model. It is friendly enough to inform the errant user of the parameters that remain to be defined.

As is true for any good software, STELLA has been modified and updated several times since it became commercially available in late 1985. The initial version used some homegrown substitutes for standard Macintosh menu selections (eg, icons representing sticks of dynamite substituted for the Cut editing command) and offered no convenient means of transferring model output to another file electronically. Similarly, data could be entered into the model only by typing in changes to the initial conditions. These and other shortcomings have been eliminated in Version 2.0, released in early 1988. The STELLA developers have divided the initial version into two packages designed for different user groups, STELLA for Business and STELLA for Education. While the basic architecture is the same for both packages, they differ in the selection of built-in functions and other subtleties. For this review, I have confined my attention to the latter.

HOW IT WORKS

As in any modeling exercise, the STELLA modeler begins by constructing a conceptual model that identifies the *essential* components of the model and the *important* relationships between them. I emphasize essential and important because a modeler must be able to sift through the multitude of components and factors inherent to a complex system and focus on those that are crucial to understanding the particular dynamics of the system that interest the modeler. The advantage of modeling is that it allows the user to simplify the system sufficiently to understand and study it, but it challenges the modeler not to simplify to the extent that the model no longer behaves in the same way as the system. For example, in studying the redfish fishery in the Gulf of Mexico, it may be interesting and true that the culinary and marketing skills of a New Orleans chef had a major impact on the fishery. Yet, for a basic understanding of how redfish populations sustain themselves in an environment that includes fishing nets, it is more important to include processes such as redfish reproductive rates, mortality rates, and fishing rates than Yuppie economics. By simplifying the model, the user can develop an understanding of the system sufficient to later ask the question, "What happens if the demand for redfish quadruples in one year, perhaps due to the success of some Cajun marketing?"

STELLA uses a hydraulic analogy for representing the conceptual model on the monitor screen. The basic elements of the model are stocks, flows, converters and input links. The icons for these are illustrated in Figure 1. Stocks are defined as components that can accumulate or lose their basic elements. In a

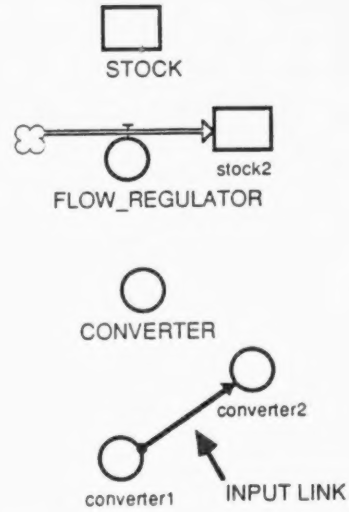


FIGURE 1. Icons used to build conceptual model diagrams in STELLA.

0742-3233/88/$0.00 + 2.00

hydraulic analogy, any vessel that can contain water (eg, cup, water tower or ocean) is a stock. In the redfish analogy, a population of redfish could be a stock, or the fleet of fishing boats may be a stock. The stock analogy is a natural for fishery population models, however a little imagination can extend it to any biological system. For the physiologist, the accumulation of acetylcholine in a pre-synaptic neuron or of free oxygen in erythrocytes may be stocks of interest. In constructing a model with STELLA, the modeler begins by placing all of the pertinent stocks on the screen and naming them.

For a stock to accumulate or lose the articles it holds, it must have a means of passage for the articles into and out of the stock. STELLA uses "flows", hydraulic pipes with control valves ("regulators"), to represent this function. The stock representing a redfish population might have flows coming into it that represent births and immigration and flows going out of it that represent natural mortality and fishing mortality (Figure 2). While the flow icons represent the concept of fish moving into and out of the population, they do not show either where the fish come from or go to, or what factors determine how many fish enter or leave the population. The sources and sinks of fish may be extraneous to the goal of the modeler, in which case, STELLA allows the modeler to be vague ("clouds" are at the appropriate end of such flows). If the modeler does want to designate the source of inflows or outflows, she can do so by planting the appropriate source stock at the appropriate end of the flow pipe. Of course this new stock may need some inflow/outflow designations, as well.

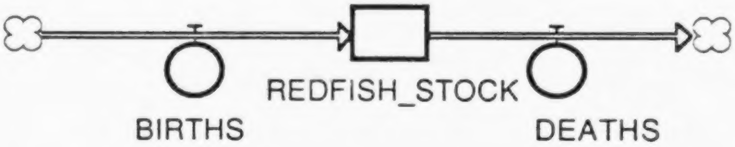


FIGURE 2. Conceptual model of a simple population model showing the model stock, flows, and converters using STELLA.

All varying flows, such as births or fishing deaths, are regulated by some additional factors. They may be dynamic factors of critical importance to the model (eg, water temperatures during the time of larval development) or other factors of unknown importance to the model. STELLA incorporates the influence of these factors, using icons for "converters", the factors, and "input links" that specify the direction of action. In the redfish model, the temperature converter acts on the regulator of the birth flow (Figure 3). Other factors that influence birth rates may be added to the model (eg, plankton abundance, larval abundance) as converters, or taken from other parts of the model already represented (eg, the population stock). Furthermore, converters can be used to influence other converters rather than flow regulators. All other stocks, flows, converters, and input links can and should be added to the diagram on the monitor screen before the modeler goes on to define the quantitative relationships between the converters and their objects of action.

STELLA allows the modeler to define the quantitative aspects of the model in either of two ways, by typing in an equation or by drawing a graphical representation of the function. For example, the modeler may not have a reliable data set on the relationship between the number of adult redfish and the number of larval redfish they produce each year, but she may have a general model for such a relationship based on studies of other species. Rather than worry about the details of unknown regression coefficients, the modeler can simply draw a graphical representation of such a relationship using the command "Become Graph" (Figure 4). On the other hand, the modeler may have derived a regression equation for the relationship between temperature and plankton abundance and the survival of redfish larvae to the end of their first year, based on years of data collection. The modeler can simply type in the equation that expresses this relationship to complete the inflow side of the model. A similar approach can be used to complete the outflow side of the model. In defining equations, a number of mathematical, logical, and trigonometric functions are available as "Built-ins" to the software.

Once the quantitative aspects of the model have been completely defined, the modeler can view the structure of the model in one of two ways. The Diagram window remains as the conceptual representation of the model, and the quantitative expression for each relationship can be viewed by opening the converter or regulator of interest. For a complete list of the equations and graphical relationships, the user can open the Equation window. Both windows can be printed by a simple command.

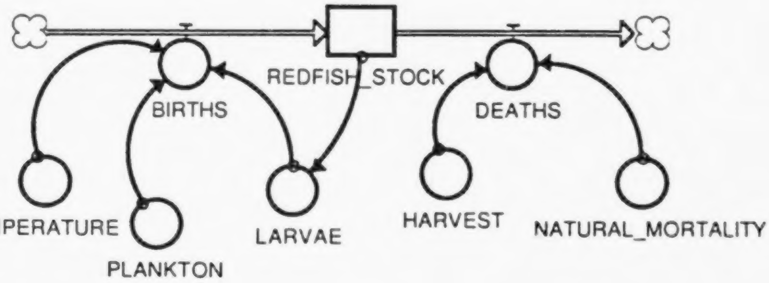


FIGURE 3. Complete conceptual diagram of a population model showing the converters and input links added to the diagram.

0742-3233/88/$0.00 + 2.00

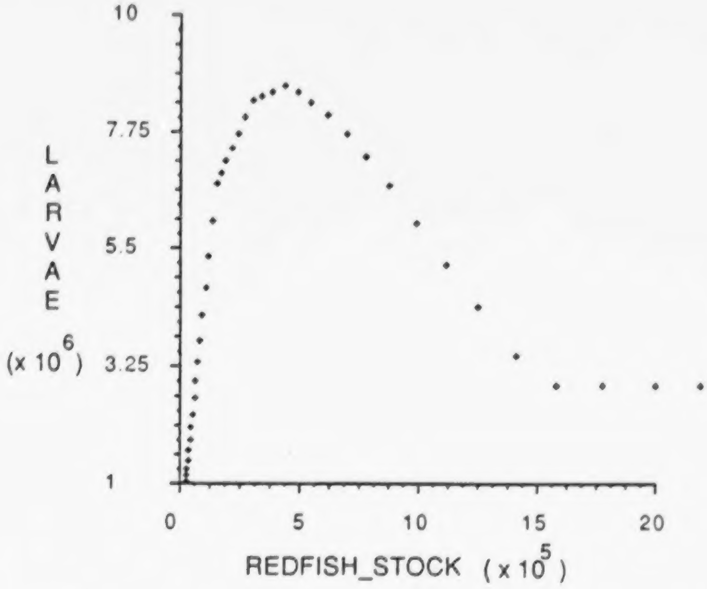


FIGURE 4. Graphical definition of the relationship between the converter "LARVAE" and the stock "REDFISH_STOCK" using the operation "BECOME GRAPH" in STELLA.

At this point, the model is ready to be run. Before running the model, the user has the opportunity to designate several aspects of the simulation technique. All models are run as time-dependent systems. Thus, the model begins with the initial conditions and makes iterative calculations to determine how the flows and stocks will change over time. The modeler can designate one of three integration methods (Euler's, 2nd-order Runge-Kutta, and 4th-order Runge-Kutta) as well as the increments of time to use in calculations and the starting and ending time for the simulation run.

The value of any of the model stocks or converters can be produced as a model output, and these can be presented in user-defined graphic and tabular forms. The graphic output can be presented as a time-series plot (Figure 5a) or as a plot of one parameter relative to another (Figure 5b). The user defines which parameters to include in the output table and at what time intervals they should be included (Table 1). Output graphs and tables can be viewed on the monitor and can be printed to an external device.

Version 2.0 allows the user to save a Diagram window or an output graph as a bit-map file accessible by "paint"-type software or as a file of PICT elements accessible by "draw"-type software. Tables and the Equation window can be saved as text files, accessible by many applications, inclding word processors and spreadsheets (tables only).

After a model is operative, the user may need to make some adjustments to assure that the model behaves like the system it represents. Adjustments to equations can be made from the Equation window or by opening the stock, converter, or regulator of interest. Additional converters and input links can be added and defined quickly, without redefining the rest of the model. The different output options and the ability to stop a simulation run before it is completed allow the user to evaluate the effects of these adjustments on the model's performance. Further tests, such as sensitivity analyses, can be performed by use of some built-in functions. Adding the PULSE function to an equation will cause the model to make a one-time and large scale change in the value of a parameter used in the simulation. Thus a pulse of plankton could be included halfway through a simulation run to determine how the model responds to a one-time alteration in the regulating conditions. Other functions allow for continuous change in the value of a parameter over time (RAMP) or discrete step-wise changes (STEP).

One of the most valuable features of STELLA is the availability of two functions that introduce user-prescribed stochastic behavior in what would otherwise be deterministic models. The RANDOM function will generate a randomly selected value between 0 and 1 to use in describing random behavior of a variable or function. The RANDOM-generated value can be modified by arithmetic transformation to obtain values drawn from any continuous probability function desired. For normally-distributed variation, the NORMAL function can be used. The default normal distribution has a mean of 0 and standard deviation of 1, however these parameters can be modified by adjusting the arguments of the NORMAL function. These functions not only allow the user to observe the sensitivity of the model to variation in the model components, but they can be used to study the influence of natural variation on the behavior of the system being modeled. This is invaluable in helping students to learn what levels of variation are important in modifying system behavior, as well as the particular parameters that are most sensative to variation.

EXAMPLES OF STUDENT PROJECTS

In the process of developing an advanced graduate course in fishery management, I was faced with the dilemma of providing students an opportunity to plan and evaluate fishery management plans without having the luxury of replicable lakes, ponds, and streams or years to carry out the experiments. Simulation seemed a viable means for the students to develop their plans and to evaluate their consequences within the reality of a classroom. A variety of mainframe and microcomputer lab facilities are available at no additional expense to the students on our campus. However, I anticipated that few of the students would have the computer skills necessary to convert their models into program code and feared that lab sessions would be little more than debugging sessions. With some frustration, I made my course plans based on a traditional review of case histories, structured discussion sessions, and required term papers.

I received a copy of the original version of STELLA the week before classes began and reviewed it immediately. It was obvious immediately that STELLA would allow me to teach the course as I wanted and within the constraints (eg, limited student programming ability) that I faced. With some trepidation, I cast aside my syllabus and outlines and embarked on an adventure of experiential learning of my own as I tried to stay ahead of the students.

My goal was simple. I wanted the students to examine and develop their understanding of how fish populations respond to environmental and human influences and how humans adjust their fishing behavior in response to the same factors. Rather than learning simply from others' mistakes and successes, they were challenged to state their own understandings in the form of models. They could then test the predictions based on these principles against the data of past fishery management practices. In the process of carrying out this exercise, they could refine and deepen their understanding of how fishery systems function, rather than simply find that their ideas were correct or incorrect.

I began the course with an introduction to the kinds of problems faced by fishery managers (relatively small data bases and relatively poor understanding of how the systems function) and then introduced the basic methods of model development and use. The first assignment was to develop a model of a catfish fishery in which fish entered the population by stocking (no natural reproduction) and were removed only by angler harvest or natural mortality. The class worked together to construct a conceptual model agreeable to everyone. They used data available in published literature and agency reports to establish the quantitative relationships between "converters" (determining factors) and "flow regulators" (processes). In the absence of documented data, they relied upon data on related species and fisheries and expert advice from fishery managers.

Once the class had their quantitative model designed on paper, I gave them a thirty minute introduction to the use of STELLA and then turned them loose in a laboratory with Macintosh computers. None of the students had used a Macintosh computer before. Within one hour, most had their model entered onto the computer and operating.

My reason for describing this sequence is to highlight how easily and how quickly students can learn to use STELLA. They need some prior instruction in the practice of modeling, some practice constructing and quantifying a simple model, and less than one hour of instruction to be able to use STELLA. As with any programming language, students become more accomplished and can create more complex models with practice. Prior programming experience certainly facilitates a more advanced approach initially. Even so, students become functionally literate in STELLA extremely quickly.

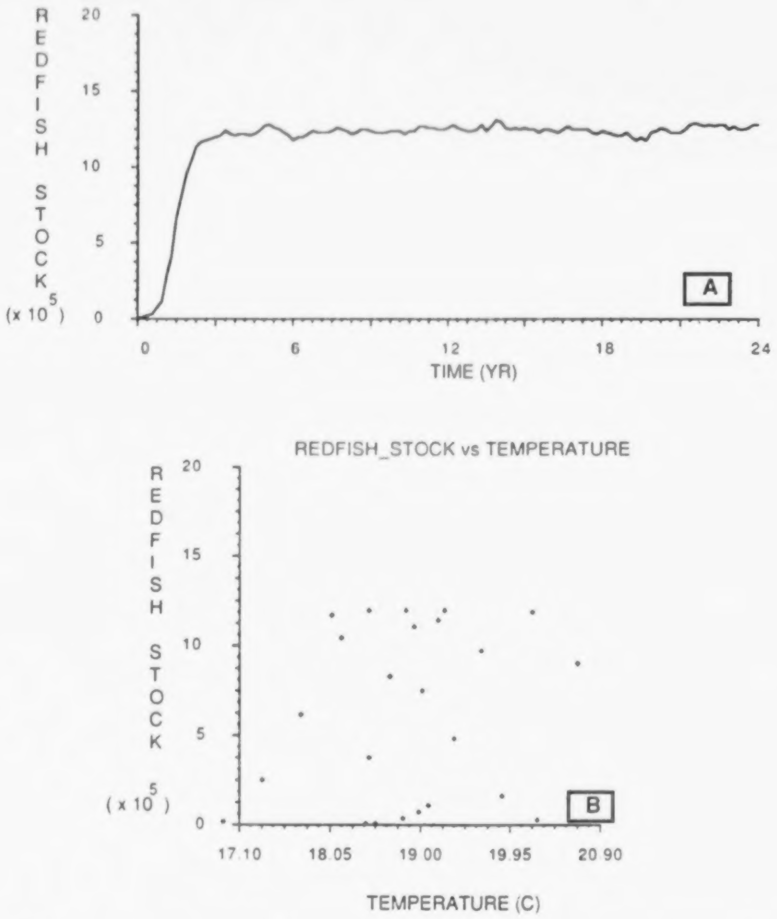


FIGURE 5. Graphical output of the population model illustrated in Figure 3 using STELLA. Graphs can be presented as time series plots (A) or as scatter plots of two variables (B). The function NORMAL was applied to converters "Temperature" and "Plankton" to generate the variation in (A).

TABLE 1. Tabular output of data generated by a simulation run of the REDFISH model using STELLA. Conditions of variation for TEMPERATURE and PLANKTON are the same as in Figure 5.

Time	REDFISH_S...	TEMPERAT...	PLANKTON	HARVEST	NATURAL_...
0.0	5000.00	20.76	243.22	950.00	1900.00
1.00	249840.59	16.25	223.74	47469.71	94939.42
2.00	1008724.6	18.66	192.74	191657.67	383315.34
3.00	1194601.3	19.35	214.39	226974.25	453948.50
4.00	1221407.9	19.90	229.57	232067.48	464134.97
5.00	1249427.1	18.15	212.31	237391.16	474782.31
6.00	1247460.6	20.51	207.53	237017.52	474035.03
7.00	1231574.4	18.41	223.52	233999.14	467998.28
8.00	1230035.9	19.45	268.25	233706.83	467413.66
9.00	1242133.0	17.65	225.50	236005.27	472010.53
10.00	1209216.9	19.34	208.97	229751.19	459502.38
11.00	1228582.4	19.41	242.13	233430.66	466861.31
12.00	1207441.1	18.90	206.85	229413.81	458827.63
13.00	1213822.5	18.51	286.60	230626.28	461252.56
14.00	1210243.1	18.38	306.84	229946.19	459892.38
15.00	1264946.0	17.00	194.24	240339.73	480679.47

After the students had used their initial model to ask some basic questions about stocking rates and harvest rates, they quickly found that their model was extremely simple to use; in fact, it was too simple. In the second version of the model, they incorporated individual growth, so that fish could be stocked at a sub-harvestable size and would grow into the harvestable size class. They could have used a variety of model structures to accomplish this, but they settled on breaking the single catfish stock of the original model into stocks of catfish of different sizes. Growth rates (ie, age of passage into the next larger size class) were determined by feeding rates and by the total density of all catfish. They increased the complexity of the outflow side of the model by incorporating length restrictions on fish harvest such that each size class had different harvest mortality rates.

Successive assignments built more demanding features into the modeling problem, yet all could be accomplished with relatively simple models. As with any modeling assignment, students tended to make models more complex than were necessary. STELLA became unwieldy and slow as model complexity increased, serving as a negative reinforcement against excessive complexity. To incorporate a more biological basis for fish somatic growth into population models, the students designed a parallel model that used millimeters of fish length as a stock that could be increased by environmentally- and dentisty-regulated growth equations. By linking a series of these length stocks, each representing an age class of fish, they could model fish growth with a von Bertalanffy model.[5] The students used the NORMAL function in an equation for recruitment of young fish into the adult stock to study the effects of random variation in environmental conditions (lake level) on the success of fish spawning and juvenile survival. The class developed all of these models as a group project which allowed them to learn from each other as well as from their own experiences.

For the final project however, I required each student to develop his or her own research problem, a model to use in studying the research problem, and a report on his or her findings from the model. This assignment was the most difficult for the students, perhaps because they had been too accustomed to the group dynamic in finding modeling tactics to accomplish their assigned tasks. The fact that they had been given the problem in previous assignments and had to define the problem in the final assignment may have also limited their success in this exercise.

LIMITATIONS TO THE USE OF STELLA

It should be obvious that I consider STELLA an asset in my teaching. Although my initial use was for a graduate course, it is quite adaptable to undergraduate courses. It is simple enough that high school students (or even junior high students) could learn to use it, as long as they are given an appropriate introduction to the methods of modeling. Yet it is powerful enough to be useful in research applications. One of our Ph.D. graduates used STELLA to model the physiological response of ruffed grouse to various winter habitat conditions. In spite of this breadth of usefulness, STELLA does have some limitations.

Perhaps the first limitation is one that some may consider a trivial one. Educational software that is usable only on a Macintosh computer is less accessible than that which is produced for all microcomputer formats. STELLA is so closely tied to the Macintosh interface that it seems unlikely that it will be available in PC or Apple II format. We are fortunate that our campus has recognized the need for PC and Mac uses and has established computer labs equipped with both types of machines. Other educators may be more limited. This is a fault of educational planners, not of the software.

My only frustrations with STELLA have come when I have tried to push it beyond a pedagogical use. STELLA can be quite useful in research applications, however its major limitation is in the size of models it can handle efficiently and its inability to link separate models in joint or successive simulation runs.

Simulation time slows considerably as the integration time steps are reduced and as the number of stocks and flows increases beyond 8 or 10. Obviously, one solution is to keep models simple, yet some applications require more detail to produce results usable in a research application. Another solution is to break cumbersome models into subunits that can be run in sequence. STELLA can be used in this way, but it requires continuous involvement of the user to move it from one step to the next. It is not designed to allow the user to automatically link these subunits into a master run, feeding output from one run as input to the next. The only way to accomplish this is to run the first subunit in the series, save the output table in a file, import this data into the next subunit as initial data, run the next subunit, feed the output to the successive subunit, and repeat these steps for each subunit. In defense of the software, this use is extending the package beyond its designed use (to teach modeling), yet it is so close to being useful in other research applications that it seems a desirable and justifiable improvement (perhaps as a "STELLA for Research").

One other limitation that concerned me involved the random number generating functions (RANDOM and NORMAL). These are extremely useful and efficiently designed functions built into the software. Yet they suffer from an inconvenient limitation. When using stochastic models, it is important to make multiple runs of the model to generate enough sets of output to determine the statistical characteristics of the model results. STELLA requires the user to initiate each simulation run directly, rather than programming the machine to run the simulation 10 or 100 times automatically and to save the appropriate output from each run.

Against the strengths of all that STELLA can do, particularly as a teaching tool, these complaints seem minor grousings. A more canny user might be capable of programming the machine to accomplish what I cannot. If these uses of the software were the goals of the designers, it should not be necessary to be a canny programmer. But the developers knew what they wanted,[3] and they succeeded remarkably well in meeting their goals. I encourage anyone interested in teaching with simulations to try STELLA. You will not turn it away.

REFERENCES

1. Eckblad, JW. Experimental data simulations in biology. Computers in Life Science Education 4:60-63, 1987.
2. Grant, WE. Systems analysis and simulation in wildlife and fisheries sciences. John Wiley & Sons, New York, NY, 1986.
3. Richmond, B. STELLA:software for bringing system dynamics to the other 98%. Proceedings of the International Conference of the System Dynamics Society 1985:706, 1985.
4. Richmond, B, S Peterson, and P Vescuso. An academic user's guide to STELLA. High Performance Systems, Inc, Lyme, NH, 1987.
5. Ricker, WE. Computation and interpretation of biological statistics of fish populations. Bulletin 191, Fisheries Research Board of Canada, 1975.

ANNOUNCEMENT

A Physiology teaching software demonstration will take place at the XXXI International Congress of Physiological Sciences in Helsinki, Finland, July 9-14, 1989. Computers will be available on-site to allow participants a hands-on experience with the programs. Authors wishing to display their software are urged to submit abstracts describing the topic, educational goals, and hardware requirements of their programs. Copies of the programs and minimal documentation (operating instructions) must be forwarded to Helsinki by June 1, 1989. Information about the software demonstration can be obtained from:

Dr. Joel Michael
Department of Physiology
Rush Medical College
Chicago, IL 60612
(312) 942-6426

Information about the Congress and the required registration material can be obtained from:
The Secretariat, XXXI International Congress of Physiological Sciences, P.O. Box 722, SF-00101 Helsinki, Finland.

AIMS AND SCOPE

The goal of *Computers in Life Science Education* is to provide a means of communication among life science educators who anticipate or are currently employing the computer as an educational tool. The range of content includes, but is not limited to, articles focusing on computer applications and their underlying philosophy, reports on faculty/student experiences with computers in teaching environments, and software/hardware reviews in both basic science and clinical education settings.

INVITATION TO CONTRIBUTORS

Articles consistent with the goals of *Computers in Life Science Education* are invited for possible publication in the newsletter.

PREPARATION AND SUBMISSION OF MATERIAL

Articles submitted for publication should not exceed 2000 words and should be typewritten, double spaced, with wide margins. The original and two copies including two sets of figures and tables should be sent to the Editor: Dr. Harold Modell, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

Title page should include full title, list of authors, academic or professional affiliations, and complete address and phone number of the corresponding author.

Illustrations should be submitted as original drawings in India ink or sharp, unmounted photographs on glossy paper. The lettering should be such that it can be legible after reduction (width of one column = 5.7 cm).

Reference style and form should follow the "number system with references alphabetized" described in the Council of Biology Editors Style Manual. References should be listed in alphabetical order by the first author's last name, numbered consecutively, and cited in the text by these numbers.

RESPONSIBILITY AND COPYRIGHT

Authors are responsible for accuracy of statements and opinions expressed in articles. All authors submitting manuscripts will be sent a copyright transfer form to complete. The completed form must be returned before the work will be published.

SUBSCRIPTION INFORMATION

Computers in Life Science Education is published monthly by National Resource for Computers in Life Science Education, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Subscription rate is $30.00 for 12 issues, including postage and handling in the United States and Canada. Add $20.00 for postage (airmail) in Mexico and Europe and $23.00 for the rest of the world.

This newsletter has been registered with the Copyright Clearance Center, Inc. Consent is given for copying of articles for personal or internal use, or for the personal or internal use of specific clients. This consent is given on the condition that the copier pay through the Center the per-copy fee stated in the code on the first page for copying beyond that permitted by the US Copyright Law. If no code appears on an article, the author has not given broad consent to copy and permission to copy must be obtained directly from the author. This consent does not extend to other kinds of copying, such as for general distribution, resale, advertising and promotional purposes, or for creating new collective works.

Address orders, changes of address, and claims for missing issues to NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Claims for missing issues can be honored only up to three months for domestic addresses and six months for foreign addresses. Duplicate copies will not be sent to replace ones undelivered due to failure to notify NRCLSE of change of address.

Address editorial correspondence to Harold I. Modell, PhD, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. (BITNET MODELL@UWALOCKE)

POSTMASTER: Send address changes to *Computers in Life Science Education*, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

0742-3233/88/$0.00 + 2.00

VOLUME 5 NUMBER 10, OCTOBER 1988 CLSEE3 5(10), 73-80, 1988 ISSN 0742-3233

COMPUTERS
IN LIFE
SCIENCE
EDUCATION

HAROLD I. MODELL
Department of Radiology
University of Washington
Seattle, Washington

MARCEL BLANCHAER
Department of Biochemistry
Faculty of Medicine
University of Manitoba
Winnipeg, Manitoba

THEODORE J. CROVELLO
Graduate Studies and Research
California State University, Los Angeles
Los Angeles, California

JAMES W. ECKBLAD
Department of Biology
Luther College
Decorah, Iowa

TSEGAYE HABTEMARIAM
School of Veterinary Medicine
Tuskegee University
Tuskegee, Alabama

DONNA LARSON
School of Nursing
Grand Valley State College
Allendale, Michigan

TERRY M. MIKITEN
Graduate School of Biomedical Sciences
University of Texas Health Science Center
San Antonio, Texas

JAMES E. RANDALL
Department of Physiology
Indiana University
Bloomington, Indiana

PATRICIA SCHWIRIAN
College of Nursing
Ohio State University
Columbus, Ohio

RICHARD STULL
College of Pharmacy
University of Arkansas
Little Rock, Arkansas

JAMES W. WOODS
Lister Hill National Center
for Biomedical Communications
National Library of Medicine
Bethesda, Maryland

DOROTHY WOOLEY-McKAY
Department of Biology
Glendale Community College
Glendale, Arizona

GLEN YOSHIDA
Department of Life Sciences
Los Angeles Southwest College
Los Angeles, California

NRCLSE

CONTENTS

NRCLSE BEGINS SOFTWARE EVALUATION PROGRAM 73
Harold I. Modell

A STUDENT'S VIEW OF COMPUTER-BASED CURRICULUM INNOVATIONS 75
Susan Erdman

KEEPING ABREAST OF THE LITERATURE 76

NRCLSE SOFTWARE EVALUATION SUBMISSION FORM 77

NRCLSE BEGINS SOFTWARE EVALUATION PROGRAM

Harold I. Modell
Department of Radiology, University of Washington, Seattle, Washington

One of the goals of NRCLSE has been to establish a peer critique mechanism for software related to life science education.[4] Over the past two years, broad issues related to the overall focus of such a program have been highlighted in CLSE, and reader input was encouraged to help define evaluation criteria.[3,5] The underlying issues, however, appear to be too complex to define simple criteria.

Recently, EDUCOM has also tried to address these issues through two evaluation efforts. The National Center for Research to Improve Postsecondary Teaching and Learning (NCRIPTAL) established an annual higher education software awards program, and EDUCOM initiated a scholarly review of academic software project. In its first year, the latter has focused on computer based learning modules in three

0742-3233/88/$0.00 + 2.00

general curricular areas, only one of which is life science related. These programs tend to illustrate aspects of the dilemma facing any evaluation process in this area.

Entries in the NCRIPTAL program undergo evaluation by instructional design experts as well as content experts. As a result, finalists in the competition tend to be at the "cutting edge" in terms of instructional design criteria and utilization of available computer capability. Thus, although some older software may be very effective in presenting material and hence potentially very helpful to educators, they may fall short of ratings that would convey this to potential users.

The guidelines for reviewers in EDUCOM's software review project reflect an assumption that the software has been designed primarily to "teach" a particular topic. Thus, programs that have been designed to augment classroom interaction or provide animated illustration material in a group setting[1,2] may not receive appropriate reviews.

Two approaches to the overall problem may be taken. The first is to delay implementing a critique mechanism until clear criteria are evident. The second is to implement a mechanism that will not be ideal but that will provide a framework in which evaluation criteria may be tested and allowed to evolve as more experience is gained. After taking the first approach for several years, it has become clear to NRCLSE that significant progress will not occur until the latter approach is attempted.

THE NRCLSE PEER CRITIQUE PROGRAM

The NRCLSE peer critique program being initiated with this month's issue of Computers in Life Science Education will serve as the first step in this process. Its initial focus will be microcomputer software (Apple II, MS-DOS, and Macintosh), and its goal will be two-fold: to provide software authors with feedback and to provide users with information. The feedback will include a critique of the software and suggestions for ways to make it more versatile. Each piece of software will be critiqued from content and instructional design standpoints. Because computer memory and mass storage are no longer limiting factors as they were several years ago, program efficiency does not seem to be as important an issue as it once was. Thus, the programs will not be examined from a computer programming standpoint.

Each author will be required to submit a written narrative addressing the following questions to give reviewers a basis for initial evaluation.

- What need prompted the development of the software?
- For what student population was the software intended?
- In what environment is the software intended to be used (eg, group discussion, independent study)?
- Why was the specific format of the software chosen? (ie, What is the underlying philosophy of the software?)
- How long has the software been used with students?
- What attempts have been made to evaluate the impact of the software, and what were the results of those evaluations?

The software (copies supplied by the author) along with copies of the narrative will be sent to at least two content reviewers and one reviewer with expertise in instructional design. The software will be returned to the author with the reviewers' comments unless the author designates that reviewers may keep the software.

FOCUS OF EVALUATIONS

Although development of specific evaluation criteria will require some experience with the critique process, guidelines, in the form of a series of questions, will be provided for the reviewers. The content reviewers will be asked to focus initially on the following questions.

- Is the content accurate?
- Does the software appear to meet the design criteria specified by the author?
- Are error messages provided where appropriate?
- Do the form of error messages (if appropriate) provide an additional learning experience for students?
- Is the software suitable for student populations or educational settings other than those specified by the author? If not, what modifications would be necessary to make the software more versatile?
- Are you aware of other software that covers the same material? If so, who are the authors, and how does this program differ from the others?
- What features did you like best about the program?
- What features did you like least about the program?

Reviewers with expertise in instructional design will be asked to examine the program with the following questions in mind.

- Are the input and output schemes followed in this program consistent with sound instructional design principles (not necessarily "state of the art")?
- How could the input and output screens be improved and still meet the program needs as stated by the author?

FUNDING FOR THE PROGRAM

Because NRCLSE has been unable to identify potential sources of funding for such a program, the program must be self funding. Each author will be required to submit a nominal fee of $25 to cover handling, mailing, and follow-up costs associated with the review process.

SOFTWARE REPORTS

To meet the goal of providing software users with information concerning available software, each complete program received will be included in the CLSE Where's the Software listing. In addition, each complete package will be considered for an in-depth review article in CLSE.

REFERENCES

1. Heckman, J, MB Wang, M Harris, M Gordon and A Cardell. The use of computer animations during lectures in physiology. Computers in Life Science Education 4:73-76, 1987.
2. Levine, SD. Microcomputer graphics as a substitute for lecture slides. Computers in Life Science Education 1:33-36, 1984.
3. Michael, JA. Letter to the editor: comment on peer review or peer critique of software. Computers in Life Science Education 4:91-92, 1987.
4. Modell, HI. Establishment of the national resource for computers in life science education. Computers in Life Science Education 3:1-5, 1985.
5. Modell, HI. How shall we evaluate software – peer review or peer critique? Computers in Life Science Education 4:68-69, 1987.

A STUDENT'S VIEW OF COMPUTER-BASED CURRICULUM INNOVATIONS

Susan Erdman

Division of Comparative Medicine, Massachusetts Institute of Technology, Cambridge, Massachusetts

Unlike the classes before them, each student of the Class of '88 of Mississippi State University College of Veterinary Medicine was required to purchase a computer upon matriculation.[1] Having been one of these students, I had the opportunity to witness, first hand, computer-based innovations in the curriculum. After four years, some of us fantasized about nationwide computerized networking systems while others imagined a 128K Macintosh computer falling twenty stories and crashing to the concrete while David Letterman's audience cheered. No doubt, the Class of '88 were pioneers, and, no doubt, the introduction of computers into the curriculum was progressive. The progress, however, was not without controversy.

The computers were added to our curriculum primarily to facilitate information management. The computer applications in the curriculum included word-processing, diagnostic tools, data organization aids, spreadsheets, and graphics. MacWrite data disks replaced the traditional hard-copy sophomore and junior course objectives. PKC diagnostic and management software was briefly introduced. Thinktank was applied to organize projects, and Jazz was applied to hypothetical practice management exercises. Portions of our freshman anatomy course utilized Filevision to computerize lessons so that information leaves coordinated with anatomical illustrations presented logically on the computer screen.[2] Today's classes also use computerized case analyses that unfold uniquely with each management decision throughout a hypothetical case.

As freshmen, most of us sat staring blankly at the computer screens. Most of us had little previous computer experience, and some had no interest in learning. Fortunately, the curriculum planners chose Macintosh computers, which are generally easy to learn to use. This standardization also created computer compatibility that facilitated exchange of information and skills. Word processing with MacWrite quickly became popular for vocational and avocational computer use from editing course objectives to polishing resumes. Only computer games were used more frequently than MacWrite. The voluminous course objectives that were presented on a computer disk were easier to store (for example, in a pocket) and access than hard-copies. Moreover, students now had the option of personalizing the course outlines for future reference. (Course objectives are currently presented with Hypercard, which further increases flexibility and accessibility of information storage by establishing software links among related data.) Although we had few opportunities to apply diagnostic software in

0742-3233/88/$0.00 + 2.00

the didactic portion of the curriculum, some students applied diagnostic software to clinical cases during the senior year. On several occasions, computer-generated differential diagnoses demonstrated their utility in the clinics.

Interestingly, on a more negative note, my classmates frequently chose to study and work from hard-copies instead of from the computer screen, perhaps because they were more comfortable with the familiar format or, perhaps, because computer screens were harder on the eyes during long hours of study. Even more serious, opponents of the computerization suggested that computers might compromise mastery of the "veterinary essentials."

Considering the burgeoning advances within the veterinary disciplines, it seems difficult to construct an appropriate and manageable knowledge base using traditional approaches. Yet, it is important that veterinarians have access to pertinent and current information. Our veterinary curriculum demonstrated that computers facilitate access to a dynamic information source that can grow with the field. Indeed, computers can help veterinarians harness some of our expanding knowledge resources to improve future veterinary care.

Who knows how much professional impact our computer experience had on the Class of '88? When the future demonstrates that computers improve veterinary services, no doubt, computers will be further integrated and utilized within our profession. The Class of '88 and their successors will be well prepared.

REFERENCES

1. Bushby, PA. Computerized veterinary medical information systems: impact on veterinary medical education. Computers in Life Science Education 3:33-36, 1986.
2. Westmorland, N. A graphics oriented database for anatomy and physiology. Computers in Life Science Education 4:54-56, 1987.

KEEPING ABREAST OF THE LITERATURE

The following citations are presented as part of a quarterly feature in CLSE designed to help readers become aware of current literature pertinent to computer applications in life science education. The feature did not appear in the September issue as regularly scheduled because of space limitations.

Bagnall RD et al: Computerised teaching of temporomandibular joint dysfunction. Br Dent J 164(4):98, 1988.

Dooling SL: Designing computer simulations. Comput Nurs 5(6):219-224, 1987.

Duchastel PC: Display and interaction features of instructional texts and computers. Brit J Educ Tech 19(1):58-65, 1988.

Eiser L: What makes a good tutorial? Classroom Computer Learning 8(4):44-47,50-51, 1988.

Gaston S: Knowledge, retention, and attitude effects of computer-assisted instruction. J Nurs Educ 27(1):30-34, 1988.

Hanes DP et al: Computer-assisted instruction in pharmacokinetics for second-year students. J Med Educ 63(4):336-338, 1988.

Hebda T: A profile of the use of computer assisted instruction within baccalaureate nursing education. Comput Nurs 6(1):22-29, 1988.

Kordas M et al: Personal computers in teaching quantitative aspects in undergraduate physioilogy. Med Educ 21(6):468-470, 1987.

New integrated video and graphics technology: Digital video interactive. Optical Information Systems 7(6):412-415, 1987.

Perspectives in CD-ROM for information storage and retrieval. Lunin LF and Schipma RB, Eds. Journal of the American Society for Information Science 39(1):30-66, 1988.

Siegel JD et al: Computerized diagnosis: Implications for clinical education. Med Educ 22(1):47-54, 1988.

Simon W: Anatomy helper: Computer-assisted anatomy instruction. Comput Methods Programs Biomed 26(1):71-74, 1988.

Simpson D et al: Application of a frame-based computer-aided learning system in clinical chemistry. Med Educ 21(5):399-404, 1987.

Smith DA: Does computer assisted instruction work? Pa Med 91(3):8, 1988.

Swanson DB et al: Assessment of clinical competence: Written and computer-based simulations. Assessment and Evaluation in Higher Education 12(3):220-246, 1987.

Thomas SB: Microcomputer telecommunications: Basic principles for health education research. Health Education 18(6):16-19, Dec-Jan, 1987-88.

Whiteside MF, Whiteside JA: Microcomputer authoring systems: Valuable tools for health educators. Health Education 18(6):4-6, Dec-Jan, 1987-88.

Wiist WH: Update on computer-assisted video instruction in the health sciences. Health Education 18(6):8-12, Dec-Jan, 1987-88.

NRCLSE SOFTWARE EVALUATION SUBMISSION FORM

The NRCLSE software evaluation program has been initiated to promote development of high quality, versatile educational software in the life sciences by providing authors with feedback from critiques by life science educators and instructional designers. To ensure that software is reviewed in an appropriate fashion, it is essential that reviewers fully understand the rationale underlying the design criteria chosen by the author and the environment for which the software is intended. Please provide the following information concerning each software package to be evaluated.

Submit 3 complete copies of the software and all supporting documentation along with $25 (to cover handling, mailing, and follow-up costs) **to Software Evaluation Program, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.**

Author's name:

Author's address:

Title of software: **Content area:**

Minimum hardware requirements:

Optimal hardware configuration:

Software requirements (operating system, etc):

Student population for which software was written:

Environment for which software is primarily intended (independent study, classroom discussion, lecture enhancement, etc):

How long has this software been used by students?

Can reviewers keep the review copy of this software?

0742-3233/88/$0.00 + 2.00

Describe the underlying philosophy of this software. What need prompted the development of this software? Why was the specific format of the software chosen? What goals did the input/ouput scheme (or screen design) address? Is documentation an integral part of the package? How is it intented to be used? (Use additional pages if necessary.)

0742-3233/88/$0.00 + 2.00

Has the software been evaluated by students?

Briefly describe the format and results of any student evaluation.

What attempts have been made to evaluate the impact of the software on student progress?

What were the results of the impact evaluation?

AIMS AND SCOPE

The goal of *Computers in Life Science Education* is to provide a means of communication among life science educators who anticipate or are currently employing the computer as an educational tool. The range of content includes, but is not limited to, articles focusing on computer applications and their underlying philosophy, reports on faculty/student experiences with computers in teaching environments, and software/hardware reviews in both basic science and clinical education settings.

INVITATION TO CONTRIBUTORS

Articles consistent with the goals of *Computers in Life Science Education* are invited for possible publication in the newsletter.

PREPARATION AND SUBMISSION OF MATERIAL

Articles submitted for publication should not exceed 2000 words and should be typewritten, double spaced, with wide margins. The original and two copies including two sets of figures and tables should be sent to the Editor: Dr. Harold Modell, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

Title page should include full title, list of authors, academic or professional affiliations, and complete address and phone number of the corresponding author.

Illustrations should be submitted as original drawings in India ink or sharp, unmounted photographs on glossy paper. The lettering should be such that it can be legible after reduction (width of one column = 5.7 cm).

Reference style and form should follow the "number system with references alphabetized" described in the Council of Biology Editors Style Manual. References should be listed in alphabetical order by the first author's last name, numbered consecutively, and cited in the text by these numbers.

RESPONSIBILITY AND COPYRIGHT

Authors are responsible for accuracy of statements and opinions expressed in articles. All authors submitting manuscripts will be sent a copyright transfer form to complete. The completed form must be returned before the work will be published.

SUBSCRIPTION INFORMATION

Computers in Life Science Education is published monthly by National Resource for Computers in Life Science Education, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Subscription rate is $30.00 for 12 issues, including postage and handling in the United States and Canada. Add $20.00 for postage (airmail) in Mexico and Europe and $23.00 for the rest of the world.

This newsletter has been registered with the Copyright Clearance Center, Inc. Consent is given for copying of articles for personal or internal use, or for the personal or internal use of specific clients. This consent is given on the condition that the copier pay through the Center the per-copy fee stated in the code on the first page for copying beyond that permitted by the US Copyright Law. If no code appears on an article, the author has not given broad consent to copy and permission to copy must be obtained directly from the author. This consent does not extend to other kinds of copying, such as for general distribution, resale, advertising and promotional purposes, or for creating new collective works.

Address orders, changes of address, and claims for missing issues to NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Claims for missing issues can be honored only up to three months for domestic addresses and six months for foreign addresses. Duplicate copies will not be sent to replace ones undelivered due to failure to notify NRCLSE of change of address.

Address editorial correspondence to Harold I. Modell, PhD, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. (BITNET MODELL@UWALOCKE)

POSTMASTER: Send address changes to *Computers in Life Science Education*, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

0742-3233/88/$0.00 + 2.00

VOLUME 5, NUMBER 11, NOVEMBER 1988

CLSEE3 5(11), 81-88, 1988 ISSN 0742-3233

COMPUTERS IN LIFE SCIENCE EDUCATION

HAROLD I. MODELL
Department of Radiology
University of Washington
Seattle, Washington

MARCEL BLANCHAER
Department of Biochemistry
Faculty of Medicine
University of Manitoba
Winnipeg, Manitoba

THEODORE J. CROVELLO
Graduate Studies and Research
California State University, Los Angeles
Los Angeles, California

JAMES W. ECKBLAD
Department of Biology
Luther College
Decorah, Iowa

TSEGAYE HABTEMARIAM
School of Veterinary Medicine
Tuskegee University
Tuskegee, Alabama

DONNA LARSON
School of Nursing
Grand Valley State College
Allendale, Michigan

TERRY M. MIKITEN
Graduate School of Biomedical Sciences
University of Texas Health Science Center
San Antonio, Texas

JAMES E. RANDALL
Department of Physiology
Indiana University
Bloomington, Indiana

PATRICIA SCHWIRIAN
College of Nursing
Ohio State University
Columbus, Ohio

RICHARD STULL
College of Pharmacy
University of Arkansas
Little Rock, Arkansas

JAMES W. WOODS
Lister Hill National Center
for Biomedical Communications
National Library of Medicine
Bethesda, Maryland

DOROTHY WOOLEY-McKAY
Department of Biology
Glendale Community College
Glendale, Arizona

GLEN YOSHIDA
Department of Life Sciences
Los Angeles Southwest College
Los Angeles, California

NRCLSE

CONTENTS

SELECTING AN AUTHORING SYSTEM 1988: HOW THE VENDORS MAKE IT MORE DIFFICULT 81
Mary S. Trainor and P. Alexandra Schultejann

FROM CAI TO ICAI: TWO EXAMPLES ALONG THE WAY 86
Joel A. Michael, Allen A. Rovick, Martha Evens, Nahkoon Kim and Mohammed Haque

SELECTING AN AUTHORING SYSTEM 1988: HOW THE VENDORS MAKE IT MORE DIFFICULT

Mary S. Trainor and P. Alexandra Schultejann
Los Alamos National Laboratory, Los Alamos, New Mexico

Selecting an authoring system can be an intimidating prospect, considering the number and diversity of systems on the market today. Most organizations contemplating an authoring system purchase have neither the time nor personnel to devote to lengthly benchmark testing.[5,8,9] Instead, these organizations are forced to make an evaluation of numerous authoring systems based solely on the information and demonstration packages provided by the vendors. The major problem posed by this approach is that these packages do not

Editor's Note

The papers in this month's CLSE were presented at the 30th International Conference of the Association for the Development of Computer-Based Instructional Systems held in Philadelphia, PA, November 7-10, 1988 and are reprinted from the proceedings of that conference.

0742-3233/88/$0.00 + 2.00

include the information necessary to evaluate the usefulness and applicability of an authoring system for the organization's purposes.

The Cognitive Systems Engineering Group at Los Alamos National Laboratory has been active in the computer-based training (CBT) field for more than three years. We have developed several prototype computer-based systems for various agencies and are well acquainted with the constraints of programming languages versus authoring systems.

This paper describes our experiences in attempting to recommend an authoring system that would best suit the purposes of our client. Our client had very specific requirements, and we were limited by both time and resources in the evaluation process. We encountered numerous difficulties in our attempt to conduct a thorough evaluation under our time and funding constraints. The information and demonstration packages provided by the vendors contained insufficient information for us to thoroughly evaluate the authoring systems. We present some suggestions to vendors on the information that should be provided to allow potential customers adequate data for evaluation. In addition, this same information can be used by potential authoring systems customers (eg training/education managers and designers) in their evaluation of authoring systems. The goals of the paper are

1) to suggest to vendors that they provide more consistent and thorough information, and
2) to encourage potential customers to be more demanding of the vendors and more educated in their evaluations.

METHODS

Selecting an authoring system should be done with some care to ensure that the system is compatible with the customer's needs and desires. We divided the selection process into four major steps:

Step 1. Define requirements

It is important to define the needs of the group that will be developing the CBT, both now and in the future. These requirements not only include such factors as the skills of the person(s) who are going to be doing the authoring but also the desired features of the courseware. A tradeoff analysis needs to be done, determining priorities, for in the development of each authoring system, priorities were set. Your priorities should match those of the system developers. For example, it is difficult to obtain an easy-to-learn interface which also allows for sophisticated instructional strategy development (eg, simulation). It also needs to be taken into account that as a CBT program grows, the level of sophistication desired increases. Thus, features which seem unnecessary now (eg, ability to jump out to a programming language, digital audio) may become highly desirable a year from now. Unless these features are anticipated, selection of a highly constraining system may occur. The specific needs and requirements for the evaluation we undertook were:

- An authoring system that is compatible with Zenith Z248's for authoring and the EIDS system for delivery.
- A system capable of handling a variety of instructional strategies, including drill and practice, tutorial, gaming and simulation.
- A computer-managed instruction (CMI) capability which allows for such features as customized record keeping, report generation, a variety of test modes, and learning prescription generation.
- The capability to incorporate other graphics and routines developed in a programming language into the authored courseware. This was desired because of future flexibility, allowing for addition of features not possible through the authoring system.
- A system that is easy-to-learn for nonprogrammers with minimal time spent on documentation.
- Versatility so that authors who become familiar with the system will be able to customize the interface to their own preferences.
- The capability to customize the feedback relative to the course and to include sophisticated answer-judging routines.
- A system that provides a variety of questioning formats.
- A system that does not charge royalties or include a separate presentation system.
- Minimum maintenance costs.
- The ability to add videodisc capability, and perhaps CD-ROM, in the future.

Step 2. Select authoring systems for in-depth evaluation

Because of the number of authoring systems on the market, it was not possible to evaluate them all. We started the narrowing down process by doing background research on authoring systems[1-4,6,7,10,11] and making a preliminary selection from the *CBT Guide to Computer-Based Training Systems and Courseware* published by Data Training and Weingarten Publications, Inc.[12] The Guide covers the basic attributes of 98 authoring systems, and Data Training provides a matrix of system features versus authoring system. The Guide, literature, and our own experience allowed us to select eleven systems as candidates for evaluation.

Step 3. Contact vendors for information and demonstration packets

All eleven vendors were contacted by phone for information about their products and for a demonstration of the system. Four vendors were not able to send demonstration discs for evaluation because they had not produced one. One vendor subsequently sent the entire authoring system for us to preview, but we did not have the 8 to 12 hours required to adequately evaluate the system. Of those having a demonstration disc, most desired a small payment for the disc ($15-25). We explained that we felt, since this was a main marketing tool of theirs and we were potential customers, we should be provided the disc free of charge. In addition, in our institution it would have cost far more than $15 to $25 to get the necessary purchasing paperwork through the system (not to mention time). All vendors cooperated, but in several instances, many phone calls were required in order to obtain the disc. We had to describe in detail who we were and the nature of the evaluation.

The printed information we received on the authoring systems consisted primarily of sales literature; many vendors did not send the pertinent technical details we required for a thorough evaluation. When queried on the phone about this, several vendors said that we were more inquiring than most of their potential customers, and thus they did not have literature prepared at that level of technical detail.

These factors contributed to this being a most time consuming and unpleasant step in the evaluation process.

Step 4. In-depth evaluation of the authoring systems

The next step was to analyze each authoring system relative to our criteria and based upon the information and demonstration packages received. Our criteria, shown in Table 1, were developed from our experience, the literature, and from the evaluation requirements. We had thought that the Data Training Guide would provide us the necessary criteria, but after reading it through, we discovered that Data Training only set the features list, and the vendors had great liberty in what they submitted under each feature. None of the information was parallel, making comparisons difficult, if not impossible. We are not faulting Data Training in this discussion, as they were providing a very useful data clearinghouse function compiling the system/vendor information.

Step 5. Recommendation of an authoring system for purchase

The last step was to examine our evaluation information and make a final selection. Unfortunately, our results were quite inconclusive because of inadequate information (see discussion of this under **RESULTS** below). We were able to narrow final candidates to three, however. Because we needed to make a recommendation, we selected

Table 1. Questions to ask when choosing an authoring system

1. **What is the cost per instructor station? per student station? What kind of agreement do I need?** If number of student stations is large and undefined at this point, then an agreement for unlimited usage and no special presentation system is probably desired.

2. **What is the royalty agreement? Am I willing to pay the vendor for each external usage of my courseware?** If unlimited distribution is desired, ask about cost of this up front.

3. **How easy-to-learn and easy-to-use is the system?** Many vendors say their system is easy, and yet they require extensive training delivered by them. Call current system users and ask them and/or try the system out for yourself to answer this question.

4. **What are the hardware requirements?** Does the system require some specialized hardware you do not have access to or cannot afford? Some vendors developed their system to run on one set of hardware and then retrofit for others. If your hardware is retrofitted, it may be awkward to use.

5. **What support does the vendor supply?** Does the vendor supply telephone consulting (you will need it as you get started)? Are software updates provided? Are the updates designed to be compatible with earlier versions?

6. **What graphics, video, input devices and audio are supported?** The power of the technology comes through in the use of high quality graphics (including overlay on video), digital audio (not just audio on videodisc), the ability to use touch or mouse as well as keyboard, and the videodisc. You may not want these now, but you probably will later. Don't bind yourself to an authoring system which is constrained and not keeping up with new technologies.

7. **Which instructional strategies are supported?** Many authoring systems constrain you to tutorial and drill and practice formats, yet the simulation and gaming strategies may be needed for a particular application. How does the vendor define a particular strategy? The vendor may define it differently than you do as well.

8. **How does the computer-managed instruction (CMI) work?** Most systems have CMI, but it may not match your needs. What record keeping and reporting do you require? Will the system require a central file server? Do you have to pay extra for CMI?

9. **What response and questioning strategies can be used?** You will want to be able to ask some open-ended questions, as well as multiple choice questions. Will the system allow for this? Does it have a built-in spelling corrector? Can several specific hints be given for different wrong answers, to aid the student in reasoning to the correct answer?

10. **How flexible is the interface for different screen designs?** Can you have different types of menus: located at different screen locations? of different sizes? with icons/graphics?

11. **Does the system support team development?** Can one person be working on graphics while another working on audio and text for the same lesson at the same time?

12. **How easy is it to change and update a lesson?** Maintenance costs can be high and maintenance is always necessary. What features does the system have to accommodate maintenance?

13. **Can it talk to programming languages?** If an authoring system has an efficient way to jump out to code written in a programming language, then it provides much greater flexibility than a system which does not have this capability. This is desirable whether you need this flexibility now or not.

14. **Can it import courseware written using other systems?** You may need to author or write scripts using other software systems, and if you can import those files into the authoring system directly, you can save a great deal of time.

0742-3233/88/$0.00 + 2.00

one of the final three systems/vendors on the basis of the degree of cooperation they gave us on the phone, their reputation, and the apparent expansibility of the system.

RESULTS

Some of our evaluation criteria were readily answerable either through the demonstration packages or in the information sheets (numbers 1,2,6,8,16). Compatibilities and system features were fairly easily determined. In fact, the authoring systems we were evaluating were remarkably similar in their features with little apparent differences to use for discrimination purposes.

In the area of cost, it became apparent that the advertised cost was very negotiable depending upon the size and nature of the contract, as well as the business of the contracting institution (eg, education or government). For example, if an institution were to purchase several authoring workstations and many student presentation systems, the price would be reduced significantly. One could only obtain this type of information on the phone through probing, and therefore many potential customers would not obtain this information. Another cost issue resulting in confusion was royalties. In our case, we did not want to have to pay royalties on internally developed and distributed courseware, but rather have the freedom of distribution. Several vendors seemed ill-prepared to cope with this requirement in terms of cost estimate, even though it seems to be a commonly held and desirable requirement in the community.

We were unable to make any judgement on several key criteria because of inadequate information. These criteria are listed and described below.

Ease-of-use

Only two of the demonstration packages included enough of the program so that a limited course could be built, giving us a true "hands-on" experience with the authoring system. Without actually trying to use the authoring system, it was impossible to evaluate ease-of-use. Similarly, without an example of documentation, we were unable to evaluate it or how much the program depended upon it. We discussed this drawback of the demonstration discs with several vendors, and they agreed with our criticism. The vendor claimed that most people evaluating the systems do not request evaluating ease-of-use and ease-of-learning (even though these are very relative) and that they would not be producing demo discs to make this possible. The only alternative they suggested was trying to use the complete authoring system package (some offered to send one on a trial basis), yet such use requires a larger time investment than we (and most potential customers) have for evaluation.

External interface

We were unable to determine the extent the authoring system was capable of interfacing with other software and programming languages. Although all of the systems we were evaluating claimed this capability, it became apparent through review of the literature that some systems were more capable than others. In one case, for example, jumping out to some external code was quite easy, but quickly jumping back into the authoring system courseware was not possible.

Computer managed instruction (CMI)

Only three of the systems evaluated included sufficient information on the CMI capabilities. The others informed you that they did have the capability of testing and record keeping, but did not provide information on the nature of the CMI interface, the number and types of records kept routinely, the method of access for students versus instructors, the learning prescription feature availability, or the types of testing possible.

Question format

Only two of the systems evaluated discussed the subject of possible question formats adequately and, then, only on the demonstration disc. Most of the systems mentioned multiple choice and fill-in as questioning modes, and some included matching and true/false. For most of the systems, we could not determine if short answer or long answer questions were possible. In addition, there are a variety of ways of designing questioning screens, and yet we had no way of knowing from the demonstration discs which types of interfaces were available for which systems and how easy they were to generate.

Customized feedback

We were able to determine the extent of customized feedback and answer judging only from the two demonstration discs that allowed us to actually build a program. These discs represented a wide range in feedback treatments possible, thus the complexity of the criterion was evident. We were interested in information such as how long the feedback could be, how many customized responses could be programmed per course, and how the answer judging was handled. This parameter was important to us, because we wanted to aid our students in reasoning to the correct answer for a problem instead of just being told "try again" or being told the right answer after only two incorrect answers. The majority of systems we evaluated did not fully discuss the subject, thus our evaluation was incomplete for this criterion.

Instructional strategies

Instructional strategy, or the method used to aid the student in achieving the objectives, is critical to a good match between the subject matter and the student needs. For example, a drill and practice strategy is adequate for learning multiplication tables but is very inadequate in assessing a student's ability to operate a particular control panel. Since most installations need to provide courseware on a variety of applications requiring a variety of instructional strategies, flexibility and robustness here was necessary. None of the systems we evaluated adequately treated the instructional strategies issue. It was also not possible to deduce this information based on the data provided in the information and demonstration packages.

Compilation

One of the systems indicated that the resultant courseware was an uncom-

0742-3233/88/$0.00 + 2.00

piled program written in a programming language. The other seven products we evaluated did not indicate if the courseware generated by the authoring language was compiled or code.

DISCUSSION AND CONCLUSIONS

The information provided by the vendors on their authoring systems was not adequate to make a thorough evaluation of the products. We found that most of the information provided by the vendors was sales- and feature-oriented rather than oriented toward the performance of the system and the modes of instruction it supports. Most of the demonstration discs we looked at were computer-based sales pitches that demonstrated samples of courses and graphics created by the authoring system. They did not indicate how the program was achieved and the amount of time one could expect to spend generating a similar course, nor did they indicate the types of instructional designs that could be generated beyond a linear set of questions and answers.

When questioned by us, the vendors agreed to the limitations of the information packages and demonstration discs. It seems, however, that we as customers are not demanding that they produce alternatives. Potential customers of the authoring systems need to be more thorough in their investigations and evaluations and more demanding of the vendors' materials. Similarly, vendors need to lend greater assistance to their prospective customers by providing the necessary information so that users can make an intelligent selection. Based on our experience, we recommend that potential customers generate a list of criteria prior to evaluation and be firm with the vendors in obtaining answers. We recommend that vendors include more detailed technical information in their sales and demonstration packages. the specifics of the additional information needed is described below.

1. Our foremost recommendation is for the vendors to allow the potential customer to actually use the authoring system in the demonstration disc. Proprietary protection can be achieved by limiting the number of screens that can be built or by not enabling a "save file" routine. It is virtually impossible to get an indication of system responses, capabilities, performance, and ease-or-use without actually using the authoring system itself. This type of demonstration disc is widely available in the "expert system shell" business, so vendors of expert systems can be contacted for details of logistics and design. The expert system shell demo discs do enable you to create and save your own mini-expert system knowledge base, and yet they are constraining enough so that you could not actually produce a fully operational expert system with them. Through the use of three of these discs we were able to make a very intelligent evaluation of the different interfaces relative to our needs.
2. Provide examples of different instructional strategies in both the sales literature and on the demonstration discs that can be achieved with the authoring system. Define what you mean by "tutorial" and "simulation", as these terms have a variety of meanings in the field. Show the types and varieties of questioning formats that are allowed within the constraints of the system.
3. Offer demonstration discs to potential customers, if only on a "borrowed" basis. Potential customers should not have to pay to obtain essential information to adequately evaluate a vendor's product.
4. Provide more technical information on the performance of the authoring system.
5. Include more information on the system's ability to interface with other software and programming languages. Also, discuss the capabilities to build library files of graphics and subroutines.
6. Include more information on the CMI package and its capabilities and applications. Give examples of the types of records possible and identify how scorekeeping is accomplished.
7. Discuss if and how feedback can be customized to fit the needs of the user. Include the constraints on customizing feedback as well as capabilities.

REFERENCES

1. Avner, A, S Smith, and P Tenczar. CBI authoring tools: effects on productivity and quality. Journal of Computer-Based Instruction 11:85-89, 1984.
2. Crider, J. Authoring system review: the educator. Journal of Computer-Based Instruction 11:101-102, 1984.
3. Hannafin, MJ. Options for authoring instructional interactive video. Journal of Computer-Based Instruction 11:98-100, 1984.
4. Heck, WC and PE Grimm. Ease: easy authoring system for educators. Journal of Computer-Based Instruction 11:72-73, 1984.
5. Hillelsohn, MJ. Benchmarking authoring systems. Journal of Computer-Based Instruction 11:95-97, 1984.
6. Kearsley, G. Computer-Based Training. Addison-Wesley, New York, NY, 1984, pp 115-122.
7. Klass, R. The TenCore language and authoring system for the IBM personal computer. Journal of Computer-Based Instruction 11:70-71, 1984.
8. Locatis, CN and VH Carr. Using a lesson-element keystroke oriented approach for estimating authoring tool efficiency. Journal of Computer-Based Instruction (in press).
9. Locatis, C and V Carr. Authoring systems and assumptions about them. Journal of Bio Communications 13:4-9, 1986.
10. Long, KT and EC Squire. Courseware's Apple authoring system. Journal of Computer-Based Instrution 11:74-75, 1984.
11. Reed, MJ and M Porter. A review of Digital's Courseware authoring system. Journal of Computer-Based Instruction 11:68-69, 1984.
12. Stein, J. The 1987 CBT Guide to Computer-Based Training Systems and Courseware. Weingarten Publications, Boston, MA, 1987, pp 1-37.

0742-3233/88/$0.00 + 2.00

FROM CAI TO ICAI: TWO EXAMPLES ALONG THE WAY

Joel A. Michael, Allen A Rovick, Martha Evens, Nahkoon Kim and Mohammed Haque
Department of Physiology, Rush Medical College, Computer Science Department, Illinois Institute of Technology and Department of Information Science, Northeastern Illinois University, Chicago, Illinois

There is a continuum of computer-based exercises,[14] each with its own advantages and limitations, that ranges from the "conventional" (CAI) to the "intelligent" (ICAI). Application of significant concepts from the field of artificial intelligence (AI) to the development of computer-based exercises, even in the absence of expensive AI "tools", can result in innovative teaching programs.

We have already written several CAI exercises in physiology.[6,8,9,10] For the past two years, we have focused on developing two tutoring programs in the domain of the cardiovascular (CV) physiology. Neither program functions at the level of an ICAI exercise; they are not yet "smart tutors". But, we have produced sophisticated programs that are of use with our (JAM and AAR) students, and at the same time, are pointing the way to our eventual development of truly "smart" program.

WHAT IS A "SMART TUTOR"

A "smart tutor" (sometimes referred to as an intelligent tutoring system or ITS) is a computer program able to assist a student in mastering some subject matter domain.[4,11] The essence of such a program is that its tutoring — its interaction with the student— is context dependent.[13] This means that the particular action it takes is determined by the current state of the student's knowledge or understanding. To produce such a behavior, a "smart tutor" must be able to:

1) model the student's understanding of, or misconceptions about, the domain being studied;[1]
2) solve the problems being presented to the student;
3) tutor the student, selecting a sequence of actions (tactics) according to some strategy that depends on the current state of the student;[13] and
4) communicate with the student in a way that reveals what the student understands; in many, but not all, cases this requirement can best be met by the ability to generate a two-way natural language conversation.[13]

As interim steps along the way to the development of our two "smart tutors", we have employed approaches to partially realize some of the above functions that do not require expensive or complex AI resources. Before describing these solutions, however, we need to briefly describe the particular programs we are working on.

"SMART TUTORS" IN CV PHYSIOLOGY

As teachers of medical physiology, we (JAM and AAR) routinely ask students to learn the behavior of complex, multicomponent systems with feedback, and to do this in a way that facilitates their ability to "solve problems". Our programs are intended to assist students in this task.

The first program assists students in solving pathophysiology problems. Here, the student is asked to first determine the pathophysiology giving rise to a constellation of signs and symptoms presented by a patient, and then to explain the origin of these features from the physiological cause they propose.[5] The general educational objective of this exercise is the development of those skills needed to apply a hypothetico-deductive problem-solving approach[2] to a particular class of problems.

A second program coaches students working with a computer simulation of the system that maintains a constant blood pressure. Here, the student predicts the changes that will occur in seven parameters following selected experimental procedures (the tutor is based on a teaching program called CIRCSIM[10]). The general educational objective of this exercise is the development of the ability to analyze the behavior of complex systems possessing feedback.[6,8]

INCORPORATING "INTELLIGENCE" INTO CAI EXERCISES

While the present versions of these two programs are not as "smart" as they will eventually be, they effectively perform some of the functions necessary for an ITS *without using sophisticated AI techniques.*

Student - computer interface

Effective tutoring will require that the student be able to communicate with the program using natural language. However, the development of a robust natural language capability, one able to understand ill-formed inputs generated by the student, and produce complex, context-dependent outputs, is a major undertaking which we have only started. In the absence of these capabilities we have developed two alternative ways for students to provide inputs that contain enough information to drive a tutorial interaction.

In the pathophysiology tutor[3] the student must:

1) identify patient signs and symptoms,
2) generate hypotheses,
3) request data,
4) validate hypotheses, and
5) provide explanations.

A menu-driven approach provides these

0742-3233/88/$0.00 + 2.00

functions at this time.

To identify pertinent patient findings, the student uses a cursor to highlight text in the description of the patient; the selected text is then saved to a file for later use by the student and by the tutor.

To generate an hypothesis to account for the findings he has selected, the student "pages" through a set of structured menus until he finds an hypothesis that he identifies as the source of the patient's problem. Data about the patient is requested by the student in a similar way. While the set of possible hypotheses or data is clearly finite, it is sufficiently large that it places no significant constraint on the students' selection — it does not suggest "answers" that the student might not have arrived at if he was working independently.

In our simulation-based program, the student makes predictions about the direction of change of specified parameters using a predictions table in which the student can move a cursor and toggle the desired entry into each cell. This set of inputs provides the tutor with an assemblage of data from which it can deduce a cognitive model of the student and then decide on the appropriate response to generate. These is clearly more information available here than in a conventional CAI situation where a student answers a single question whose correctness is assessed and used to select feedback.

Expert problem-solvers

A "smart tutor" must itself "understand" the subject matter so that it can solve the problems presented to the students and interpret students' responses.

For example, in a simulation-based tutor, the simulation itself is an expert problem-solver in that it calculates the behavior of the system for each input.[7] Thus, whether the student is asked to make qualitative predictions about the system, or to calculate the quantitative responses he expects, the correct answer is internally available.

Alternatively, in many domains it is possible to develop rule-based qualitative models with which to generate predictions and explanations about system behavior.[12] This is the approach that we have taken with the preliminary version of our CV simulation tutor. An algorithm has been written with which the qualitative behavior of the system to any input can be determined. Such an approach enables one to model complex systems where an analytical model may be too difficult to generate, or where sufficient data is not available upon which to base such a model.

Where the nature of the exercise does not permit a model-based approach, one may use a stored data-base of solutions to the problems to be presented. This is the approach we have taken with the pathophysiology tutor where we are dealing with a necessarily small number of problems (both because there are a limited number of patient problems that are relevant to our educational objectives, and because the time required to solve each problem is sufficiently long that the student can only do one or two problems at a sitting). Solutions to each of the three problems in our exercise are stored using an approach that resembles a data-base program.

Student-modelling

Conventional CAI generally utilizes conditional branching from individual answers to determine the particular feedback to be provided or the next step in the exercise to be pursued. While this "individualizes" the students' experience in some limited sense, it provides a fixed response to any wrong answer *regardless of the reason that the student answered incorrectly*. However, the same incorrect response can result from great differences in students' general background, available knowledge about the domain, or skill at problem-solving.

A "smart tutor" attempts to provide a deeper level of assistance to the student by determining the specific basis for the wrong answer. This process of modeling the "cognitive state" of the student is amongst the most difficult confronting the development of ICAI programs.

Our approach to student modeling in our simulation tutor, one with general applicability, is based on a concept map of the relevant domain and an experimentally derived catalog of student "bugs". Predictions for a minimum of seven parameters are available as each experiment is carried out. Particular patterns of errors then allow the modeler to pick from the list of "bugs" the most probable source of the students' incorrect responses. For example, errors in predicting the changes that will occur in CC, HR, and TPR *and* the failure to have entered these predictions sequentially suggests that the student does not understand the common neural control of these parameters. With such information available to the "tutor", the most helpful intervention can then be selected.

SUMMARY

The development of sophisticated tutoring programs, programs able to tailor their interactions with the student to meet the students' specific needs, will go a long way towards overcoming many of the limitations of current CAI. There is much to be learned from the fields of artificial intelligence and cognitive science that is relevant to this effort, even if the technical resources to implement these ideas are unavailable. It is ultimately the ideas that are most relevant, not the use of any particular AI programming language or AI work station.

REFERENCES

1. Clancey, WJ. Qualitative student models. Ann Rev Comput Sci 1:381-50, 1986.
2. Elstein, AS, LS Shulman, and SA Sprafka. Medcial problem solving: an analysis of clinical reasoning. Harvard University Press, Cambridge, MA, 1978.
3. Haque, MM, M Evens, JA Michael, and AA Rovick. A physiology tutor based on an expert system. Proc ESD/SMI 1st Ann Exp Sys Conf, Dearborn, MI, 1987, pp 423-436.
4. Lawler, RW and M Yazdani (eds). Artificial intelligence and education. Volume 1, Learning environments and tutoring systems. Ablex, Norwood, NJ, 1987.
5. Michael, JA and AA Rovick. CV pathophysiology problems in small group tutorials. The Physiologist 26:225-228, 1983.

0742-3233/88/$0.00 + 2.00

6. Michael, JA and AA Rovick. Computer simulated experiments in the teaching of physiology. Proc 6th Ann Nat Educat Comput Conf, Dayton, OH, 1984, pp 20-24.
7. Michael, JA and AA Rovick. Computer simulations used in teaching: how to generate them. Collegiate Microcomputer 4:201-207, 1986.
8. Michael, JA and AA Rovick. The uses of CBE in teaching the functions of complex systems. Proc 27th International ADCIS Conf, New Orleans, LA, 1986, pp 43-48.
9. Rovick, AA and L Brenner. HEARTSIM: a cardiovascular simulation with didactic feedback. The Physiologist 26:236-239, 1983.
10. Rovick, AA and JA Michael. CIRCSIM: an IBM PC computer teaching exercise on blood pressure regulation. XXX Cong of International Union of Physiol Sciences, Vancouver, BC, 1986.
11. Sleeman, D and JS Brown (eds). Intelligent tutoring systems. Academic Press, London, 1982.
12. White, BY and JR Frederiksen. Qualitative models and intelligent learning environments. *In* Lawler, RW and M Yazdani (eds), Artificial intelligence and education. Volume 1, Learning environments and tutoring systems. Ablex, Norwood, NJ, 1987 pp 281-305.
13. Woolf, BP. Context dependent planning in a machine tutor. Unpublished doctoral dissertation, Department of Computer and Information Science, University of Massachusetts, Amherst, MA.
14. Yazdani, M. Intelligent tutoring systems: an overview. *In* Lawler, RW and M Yazdani (eds), Artificial intelligence and education. Volume 1, Learning environments and tutoring systems. Ablex, Norwood, NJ, 1987, pp 183-201.

AIMS AND SCOPE

The goal of *Computers in Life Science Education* is to provide a means of communication among life science educators who anticipate or are currently employing the computer as an educational tool. The range of content includes, but is not limited to, articles focusing on computer applications and their underlying philosophy, reports on faculty/student experiences with computers in teaching environments, and software/hardware reviews in both basic science and clinical education settings.

SUBSCRIPTION INFORMATION

Computers in Life Science Education is published monthly by National Resource for Computers in Life Science Education, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Subscription rate is $40.00 for 12 issues, including postage and handling in the United States and Canada. Add $20.00 for postage (airmail) in Mexico and Europe and $23.00 for the rest of the world.

This newsletter has been registered with the Copyright Clearance Center, Inc. Consent is given for copying of articles for personal or internal use, or for the personal or internal use of specific clients. This consent is given on the condition that the copier pay through the Center the per-copy fee stated in the code on the first page for copying beyond that permitted by the US Copyright Law. If no code appears on an article, the author has not given broad consent to copy and permission to copy must be obtained directly from the author. This consent does not extend to other kinds of copying, such as for general distribution, resale, advertising and promotional purposes, or for creating new collective works.

Address orders, changes of address, and claims for missing issues to NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Claims for missing issues can be honored only up to three months for domestic addresses and six months for foreign addresses. Duplicate copies will not be sent to replace ones undelivered due to failure to notify NRCLSE of change of address.

Address editorial correspondence to Harold I. Modell, PhD, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. (BITNET MODELL@UWALOCKE)

POSTMASTER: Send address changes to *Computers in Life Science Education*, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

0742-3233/88/$0.00 + 2.00

VOLUME 5, NUMBER 12, DECEMBER 1988

CLSEE3 5(12), 89-96, 1988 ISSN 0742-3233

COMPUTERS
IN LIFE
SCIENCE
EDUCATION

HAROLD I. MODELL
Department of Radiology
University of Washington
Seattle, Washington

MARCEL BLANCHAER
Department of Biochemistry
Faculty of Medicine
University of Manitoba
Winnipeg, Manitoba

THEODORE J. CROVELLO
Graduate Studies and Research
California State University, Los Angeles
Los Angeles, California

JAMES W. ECKBLAD
Department of Biology
Luther College
Decorah, Iowa

TSEGAYE HABTEMARIAM
School of Veterinary Medicine
Tuskegee University
Tuskegee, Alabama

DONNA LARSON
School of Nursing
Grand Valley State College
Allendale, Michigan

TERRY M. MIKITEN
Graduate School of Biomedical Sciences
University of Texas Health Science Center
San Antonio, Texas

JAMES E. RANDALL
Department of Physiology
Indiana University
Bloomington, Indiana

PATRICIA SCHWIRIAN
College of Nursing
Ohio State University
Columbus, Ohio

RICHARD STULL
College of Pharmacy
University of Arkansas
Little Rock, Arkansas

JAMES W. WOODS
Lister Hill National Center
for Biomedical Communications
National Library of Medicine
Bethesda, Maryland

DOROTHY WOOLEY-McKAY
Department of Biology
Glendale Community College
Glendale, Arizona

GLEN YOSHIDA
Department of Life Sciences
Los Angeles Southwest College
Los Angeles, California

NRCLSE

CONTENTS

KEEPING ABREAST OF THE LITERATURE 89

INDEX FOR VOLUME 5 90

CUMULATIVE AUTHOR INDEX FOR VOLUMES 1-5 91

CUMULATIVE SUBJECT INDEX FOR VOLUMES 1-5 93

KEEPING ABREAST OF THE LITERATURE

The following citations are presented as part of a quarterly feature in CLSE designed to help readers become aware of current literature pertinent to computer applications in life science education.

Armistead LP et al: Impact of microcomputers on community college faculty. Community College Review 15(2):38-44, 1987.

Bergeron BP: Toward more effective learning environments: Strategies for computer simulation design. Collegiate Microcomputer 6(4):289-309, 1988.

Browning ME et al: A problem solving tutor for introductory genetics in Turbo PASCAL. Collegiate Microcomputer 6(2):113-122, 1988.

Goolkasian P et al: A computerized laboratory for general psychology. Teaching of Pyschology 15(2):98-100, 1988.

Greaf WD: Computer-assisted instruction: Is it right for you? Journal of Continuing Education in the Health Professions 8(2):97-105, 1988.

Ingram D: Computer models and simulations in medical education. Interactive Learning International 4(2):33-35, 1987.

Marcoulides GA: An intelligent computer based learing program. Collegiate Microcomputer 6(2):123-126, 1988.

Micol JL: Two different approaches to computer-aided teaching of microbial genetics. Comput Appl Biosci 3:89-92, 1987.

Pogue RE: Computers in nursing education. Where is the educational perspective? Comput Nurs 6:94-96, 1988.

0742-3233/88/$0.00 + 2.00

Sarvela PD et al: Testing and computer-based instruction: Psychometric considerations. Educational Technology 28(5):17-20, 1988.
Stonebraker PW et al: Teaching with personal computers. College Teaching 36(2):69-74, 1988.
Strang HR: A microcomputer-based laboratory experience to assist undergraduate students in learning basic concepts in human memory and retention. Collegiate Microcomputer 6(2):184-188, 1988.
Sturtevant V et al: Micro-computer test-generation systems: A software review. Teaching Sociology 16(1):49-54, 1988.
Warner, M: Developing database files for student use. Computing Teacher 15(7):44-47, 1988.
Watt ME et al: A tape-based system of interactive video for computerized self-instruction. Med Teach 9:309-315, 1987.
Woods JW et al: Teaching pathology in the 21st century. An experimental automated curriculum delivery system for basic pathology. Arch Pathol Lab Med 112:852-856, 1988.

COMPUTERS IN LIFE SCIENCE EDUCATION, VOLUME 5 INDEX

analog-to-digital conversion, 4:26
annual report, NRCLSE, 2:9-10
Apple //e gameport, 4:26
Apple //e workstations, 4:25-28
authoring systems, 11:81-85

Barbee DD, 1:5-8
Blakely L, 1:1-4
bulletin board, 8:61-63

CLSE colleague directory, 2:11-15, 3:17-23, 4:29-32
cardiovascular physiology, 1:5-6, 7:49-56, 11:86
computer-aided instruction (CAI), 11:86-88
Coon TG, 9:65-71

databases, laboratory, 1:3-4
diagnosis game, 1:5-8
diagnostic practice, 1:5-8
diagnostic problems, 1:5-8

Erdman S, 10:75-76
evaluation
  of authoring systems, 11:81-85
  of software, 10:73-75
Evens M, 11:86-88
expert systems, 6:41-44
EXSYS, 6:43-44

fault games, 1:5-8
Feiner SA, 1:5-8

Graham MM, 8:57-60

Haque M, 11:86-88
hemolysis, 4:26-27
HyperCard, 5:33-34
Hypertext, 5:33-34

intelligent computer-aided instruction (ICAI), 11:86-88
interface, photosensitive, 4:25-28

Keeping Abreast of the Literature, 3:23, 6:47-48, 10:76, 12:89-90
Kiel JW, 7:49-56
Kim N, 11:86-88
Kolitsky MA, 4:25-28

laboratory,
  data acquisition, 1:2-3
  physiology, 4:25-28
  photosensitive interface in, 4:25-28
laboratories, lessons from, 1:5-8
language, graphic simulation, 7:49-56, 9:65-71
literature, keeping abreast of, 3:23, 6:47-48, 10:76, 12:89

Macintosh, 5:33-35, 7:49-56, 9:65-71, 10:75-76
Michael JA, 11:86-88
model, pulse pressure, 7:51-54
Modell HI, 8:57-60, 10:73-75

Nagy MC, 6:41-44
NRCLSE
  annual report, 2:9-10
  software evaluation program, 10:73-75
nuclear medicine, 8:57-60

peer critique of software, 10:73-75
Peterson NS, 1:5-8
photosynthesis, 1:3
physiology,
  cardiovascular, 7:50-56, 11:86
  muscle, 4:27
  plant, 1:1-4
  respiratory, 1:6-8, 4:27-28
  simulations, 7:49-56
  undergraduate, 4:25-28
plant physiology, 1:1-4
pulse pressure, model, 7:51-54

red blood cell hemolysis, 4:26-27
respiratory physiology, 1:6-8, 4:27-28
Rovick AA, 11:86-88

Schultejann PA, 11:81-85
Shepherd AP, 7:49-56
simulation
  laboratory, 8:57-60
  language, 7:49-56, 9:65-71
  wildlife management, 9:66-70
smart tutors, 11:86-88
software
  authoring systems, 11:81-85
  available, 5:35-39, 6:45-46
  evaluation forms, 10:77-79
  evaluation program, 10:73-75
  expert systems, 6:43-44
  HyperCard, 5:33-34
  information report, 8:63
  LabView, 7:49-56
  peer critique of, 10:73-75
  simulation, 7:49-56, 8:57-60, 9:65-71
  sources, 5:39, 6:46-47, 7:49, 7:56
  STELLA, 9:65-71
STELLA simulation software, 9:65-71

Trainor MS, 11:81-85

veterinary curriculum, 10:75-76

well counter simulation, 8:57-60
wildlife management, 9:66-70
Wooley-McKay D, 5:33-34

0742-3233/88/$0.00 + 2.00

COMPUTERS IN LIFE SCIENCE EDUCATION CUMULATIVE AUTHOR INDEX FOR VOLUMES 1-5

Aucone, M. *see* Jones, M.E.

Aucone, Michael *see* Jones, Michael E.

Azbell, Janet W. Conversion of instructional videotapes to vomputer controlled formats for continuing medical education. 3:27-30

Barbee, David D. *see* Peterson, Nils S.

Barr, Lloyd Computer-aided data acquisition in an undergraduate physiology laboratory. 1:19-22

Blakely, Larry First steps using personal computers in a plant physiology course. 5:1-4

Blanchaer, Marcel, C. PILOT: The language of choice for computer-assisted learning on microcomputers. 3:37-39

Blanchaer, Marcel C. Stimulating basic health science learning with clinical simulations on a microcomputer. 1:14-15

Blanchaer, M.C. Microcomputer-led clinical case tutorials in basic science education. 3:25-27

Blumhardt, Ralph *see* Lasher, John C.

Bolles, John R. Generic videodiscs: An educational resource. 2:73-76

Boyden, Patrick C. Which aspects of software are copyrightable? 2:57-57

Brubeck, J. Dale Networking CBE in health sciences. 1:41-44

Bushby, Philip A. Computerized veterinary medical information systems: Impact on veterinary medical education. 3:33-36

Cardell, Anthony *see* Heckman, James

Carr, Victor *see* Locatis, Craig

Churchill, Lynn D. Instructional design issues and the effective use of graphics in computer-assisted instruction. 2:45-47

Clark, Carl O. Computer interfacing for science experiments. 2:59-61

Coleman, Thomas G. Simulation of biological systems – what should we expect from such activity? 1:11-14

Collins, Michael A.J. The evolution of a microcomputer center. 3:76-79

Comer, Ronald C. Professionals in computer-based education and training. 1:37-38

Coon, Thomas G. Using STELLA simulation software in life science education. 5:65-71

Cooper, Elizabeth H. Simulated experiments in biology classes. 3:57-59

Coyne, Mary D. Substitution of Apple computers for storage oscilloscopes and polygraphs. 2:81-86

Craig, James F. From computerless to computer literate through resource sharing. 4:89-91

Crovello, Theodore J. Computers in biology education: Formal coursework at Notre Dame. 1:44-46

Eckblad, James W. Experimental data simulations in biology. 4:60-63

Eckblad, James W. The transfer of video images to microcomputers. 2:78-79

Eckblad, James W. Transferring BASIC programs from the Apple II to the IBM-PC. 3:49-52

Erdman, Susan A student's view of computer-based curriculum innovations. 5:75-76

Evens, Martha *see* Michael, Joel A.

Feiner, Stephen A. *see* Peterson, Nils S.

Fine, James S. Adaptation of interactive videodisc in medical education. 4:12-15

Ford, Richard T. Computer assisted instruction for teaching dental treatment planning. 4:81-84

Giles, Robert H. Uses of micro-computers in systems ecology and wildlife management instruction. 4:9-12

Gordon, Albert *see* Kastella, Ken

Gordon, Michael *see* Heckman, James

Graham, Michael M. *see* Modell, Harold I.

Graham, Stephen N. Tools for creating lessons on a computer. 2:1-5

Halsey, Eric Video signals and devices in interactive video systems. 3:12-15

Haque, Mohammed *see* Michael, Joel A.

Harless, William G. Technology in medical education – a case study approach. 2:92-94

Harris, Michael *see* Heckman, James

Heard, Barbara K. *see* Heard, John, Jr.

Heard, John, Jr. Video-based instruction as an enhancement to computer learning. 2:43-45

Heckman, James The use of computer animations during lectures in physiology. 4:73-76

Heckman, James *see* Wang, Michael

Heidcamp, William H. Computers and undergraduate comparative physiology. 1:54-55

Holliday, Charles W. Using "Human," a comprehensive physiological model, in teaching undergraduate physiology courses. 2:41-43

Jelemensky, Linda Craig Nursing education and microcomputers: Factors to consider. 2:67-71

Jensh, Ronald P. Use of computer assisted instruction – interactive video in basic medical education. 4:65-68

Johnson, Beth A. A survey of medical/health science interactive instructional materials. 2:49-56

Jones, M.E. Factors influencing the success of CAI programs. 2:61-63

Jones, M.E. Failed CAI: Where did all the effort go? 2:65-67

Jones, M.E. Simulated laboratory experiments. 2:76-77

Jones, M.E. The use of drivers in computer-assisted instruction. 2:86-87

Jones, Michael E. Teaching clinical medicine using computer aided instruction. 3:59-62

0742-3233/88/$0.00 + 2.00

Kabo, J. Michael Computer reconstruction of a human arm from serial sections. 2:14-16
Kastella, Ken Use of electronic blackboard teleconference teaching at a remote site. 4:33-35
Kiel, J.W. A graphic computer languare for physiology simulations. 5:49-56
Kim, Nahkoon *see* Michael, Joel A.
Knoll, K. Richard *see* Stull, Richard E.
Knoll, Richard *see* Stull, Richard
Kolitsky, Michael A. Apple //e mediated workstations in the undergraduate physiology laboratory. 5:25-28

Lancaster, Jack L. *see* Lasher, John C.
Larson, Donna E. Using computer-assisted instruction in the education of health care professionals: What the dean needs to know. 1:65-67
Lasher, John C. Teaching radiologic principles by microcomputer in small group conferences 1:29-32
Levine, Sherman D. Microcomputer graphics as a substitute for lecture slides 1:33-36
Locatis, Craig Factors to consider when choosing an authoring system. 2:5-7

Macias, John D. MENTOR: A computer program to teach the differential diagnosis process. 3:52-55
Maffly, Roy H. *see* Macias, John D.
Malone, Judy A. Computer culture shock: A case for affective education. 2:9-11
Mann, J.W. *see* Jones, M.E.
Mann, John W. *see* Jones, Michael E.
Manski, Richard *see* Craig, James F.
Meals, Roy A. *see* Kabo, J. Michael
Meinke, W.J. Computer-based exam construction in microbiology and immunology: the MITI bank. 1:39
Meyers, Roy S. Creative educational use of software written by others. 4:25-32
Michael, Joel A. Computer simulations in life science education: Some design issues. 3:73-76
Michael, Joel A. From CAI to ICAI: Two examples along the way. 5:86-88
Michael, Joel A. Letter to the editor: Comment on peer review or peer critique of software. 4:91-92
Michael, Joel A. Making CBE programs "smart": One goal of artificial intelligence research. 3:19-22
Michael, Joel A. *see* Rovick, Allen A.
Mikiten, Terry M. Enhancing lectures with a microcomputer. 1:9-11
Modell, Harold I. Approaches to simulations for teaching. 3:41-45
Modell, Harold I. Editorial Comment: The role of computers in the student laboratory. 4:25-30
Modell, Harold I. Editorial Comment: Reflections and future directions. 2:89-92
Modell, Harold I. Establishment of the National Resource for Computers in Life Science Education. 3:1-5
Modell, Harold I. How shall we evaluate software – peer review or peer critique? 4:68-69
Modell, Harold I. Input/output design for different educational settings. 1:57-62
Modell, Harold I. NRCLSE begins software evaluation program. 5:73-75
Modell, Harold I. Use of a computer simulation to reinforce wet labs in nuclear medicine. 5:57-60
Modell, Harold I. Using the computer in the classroom – first steps. 1:1-3
Modell, Harold I. Technical aspects of using microcomputers in a group setting. 2:35-38
Modell, Harold I. *see* Michael, Joel A.
Mosley, Mary Lou Solving an instructional problem with interactive video. 1:49-50
Moore, John F. An entry-level approach to interactive video program development. 3:9-12
Murphy, Bruce J. Developing computer assisted instruction for anatomical science education. 3:65-67

Nagy, Monica C. An overview of expert systems. 5:41-44

Olivo, Richard F. Selecting an analog-digital interface: A tutorial. 3:89-93

Parsons, Robert *see* Meyers, Roy S.
Peterson, Nils S. Diagnostic practice reinforces lessons from laboratories. 5:5-8

Robinson, Steven L. DISCOURSE – A technology based alternative for group instruction 4:17-20
Rothe, Carl F. Cardiovascular interactions – a simulation package to help learning. 4:49-53
Rovick, Allen A. The computer lesson. 1:6-7
Rovick, Allen A. *see* Michael, Joel A.

Schottelius, Byron A. Teaching physiology by microcomputer in small group conferences. 1:4-6
Schultejann, P. Alexandra *see* Trainor, Mary S.
Shepherd, A.P. *see* Kiel, J.W.
Skiba, Diane J. Evaluation of computer-assisted instruction courseware. 2:11-14
Sprague, Ruth M. JANUS – A computer interface between laboratory and lecture. 3:69-70
Stein, Randall *see* Barr, Lloyd
Stevens, F.C. *see* Blanchaer, M.C.
Story, Naomi O. *see* Mosley, Mary Lou
Stull, Richard Creative equipment acquisition for development of computer software. 2:33-35
Stull, Richard E. Projecting computer displays. 4:76-77

Townsend, DeWayne *see* Ford, Richard T.
Trainor, Mary S. Selecting an authoring system 1988: How the vendors make it more difficult. 5:81-85
Troncale, Joseph A. Computer-assisted instruction in a family practice curriculum: Two years later. 3:17-19
Tucker, Clyde How can you determine which educational software is best for your application? 1:51-53
Tymchyshyn, Patricia Computer proliferation: An experience to share. 1:67-70

Vincenzi, Frank F. Projecting microcomputer images in the classroom: a comment on two projection monitors. 1:17-19

- **Walters, Jim**
  - *see* Mosely, Mary Lou
- **Wang, Michael** Computer-based laboratory exercises. 4:57-60
- **Wang, Michael B.**
  - *see* Heckman, James
- **Washington, Dany J.** Designing computer assisted instruction materials for remedial freshman biology curriculum 2:17-22
- **Westmoreland, Nelson** A graphics oriented database for anatomy and physiology. 4:54-56
- **Woods, James W.** Letter to the editor: Comment on PILOT. 3:55
- **Woods, James W.** Optical videodiscs and computers in life science education. 1:25-28
- **Wooley-McKay, Dorothy** HyperCard – What is it? 5:33-34
- **Wooley-McKay, Dorothy** Planning and developing a microcomputer laboratory for use in a community college biology curriculum. 3:67-68
- **Wooley-McKay, Dorothy** Use of computer tutorials in community college human anatomy and physiology classes. 1:36-37

- **Yoder, Marianne E.** Syntax differences between SuperPILOT and PC PILOT. 4:20-22

COMPUTERS IN LIFE SCIENCE EDUCATION CUMULATIVE SUBJECT INDEX FOR VOLUMES 1-5

- **Affective education** 2:9-11
- **Analog-to-digital conversion** 3:89-93, 4:28-30, 5:26
- **Anatomy** 1:36, 3:65-67, 4:54-56, 4:65-68
  - of arm 2:14-16
- **Animal behavior data simulation** 4:61
- **Animation** 2:47, 4:73-76
- **Annual report,** NRCLSE 5:9-10
- **Apple PILOT** 3:38
- **Apple II, IBM-PC program conversion** 3:49-52
- **Apple //e gameport** 5:26
- **Apple //e workstations** 5:25-28
- **Applesoft BASIC** 3:50-51
- **Arm,** anatomy of 2:14-16
- **Artificial intelligence** 3:19-22
  - information sources 3:22
- **Ascultation** 1:49
- **Authoring systems** 5:81-85
- **Axon**
  - action potential model 2:26-29
  - simulation of 1:5

- **BASIC,** transferring programs 3:49-52
- **BASICA** 3:50-51
- **Basic science**
  - computer simulations and 1:14
- **Biological systems,** simulation of 1:11-14
- **Biology** 1:44, 4:60-63
  - microcomputer laboratory for 3:67-68
  - remedial education in 2:17-22
  - simulated experiments in 3:57-59
  - workstations in 2:81-82
- **Bulletin board** 1:70-71, 2:39, 3:6, 3:30-31, 3:79, 4:78, 5:61-63
- **Carbon dioxide transport** 1:58
- **Cardiovascular simulations** 1:5, 4:49-53
- **Cardiovascular physiology** 4:28, 4:49-53, 4:54-55, 4:73-76, 5:5-6, 5:49-56, 5:86
- **Case studies** 2:92-94
- **Classroom use of computers** 1:1-3
- **Clinical case tutorials** 4:25-27
- **Clinical medicine,** using computer aided instruction for 3:59-62
- **Clinical simulations** 1:14
- **CLSE colleague directory** 3:81-87, 4:1-8, 4:15, 5:11-15, 5:17-23, 5:29-32
- **Color** 2:47
- **Communication system** 4:17-20
- **Computer-assisted instruction** 5:86-88
  - for anatomical science education 3:65-67
  - in clinical medicine teaching 3:59-62
  - for dental treatment plamning 4:81-84
  - drivers in 2:86-87
  - in family practice curriculum 3:17-19
  - graphics in 2:45-47
  - in nursing 2:67-71
  - in remedial biology 2:17-22
  - success of 2:61-63, 2:65-67
  - videodiscs in 2:43-45, 2:73-76, 2:92-94, 4:65-68
- **Computer-assisted learning languages** 5:36-39
- **Computer lesson,** structure of 1:6
- **Computer literacy** 4:89-91
  - effective teaching of 2:9-11
- **COMPUTERSCOPE** 2:81-86
- **Conferences,** teaching in, 1:4, 1:60
- **Copyright** 2:57-59
- **Cost-effectiveness of CAI** 1:66
- **Courseware**
  - available 2:23-24, 2:49-56
  - copyright of 2:57-59
  - creation of 2:1-7
  - evaluation of 2:11-14
  - remedial 2:17-22

- **Data acquisition** 1:19, 1:54
- **Data simulations** 4:60-63
- **Database**
  - graphics oriented 4:54-56
  - laboratory 5:3-4
- **Database services** 1:42
- **Debuggy,** smart tutor program 3:20-21
- **Dental education** 4:81-84; 4:89-91
- **Dental treatment planning** 4:81-84
- **Diagnosis**
  - game 5:5-8
  - simulated 1:15
- **Diagnostic practice** 5:5-8
- **Diagnostic problems** 5:5-8
- **Differential diagnosis process,** computer program for teaching 3:52-55
- **Digital image processors** 2:77-79
- **Digital-to-analog conversion** 3:91
- **Direct memory access** 3:92
- **Discourse** 4:17-20
- **Drills** 1:54
- **Drivers** 2:86-87

- **Ecology** 4:9-12, 4:61
- **Education**
  - anatomical science 3:65-67
  - basic science 3:25-27
  - continuing medical 3:27-30
  - grade analysis software 3:63
  - medical 4:12-15, 4:65-68
  - test generator software 3:63

  veterinary medical 3:33-36
Electrohome projection monitor 1:18
Electronic blackboard 4:33-35
Evaluation
  of authoring systems 5:81-85
  of software 5:73-75
Examinations 1:39
  drivers and 2:86-87
  in remedial biology 2:20-21
Experiments
  interfacing with 2:59-61
  simulations of 2:76-77
Expert systems 5:41-44
EXSYS 5:43-44

Family practice 3:17-19
Fault games 5:5-8
Filevision 4:54-56
Function generators, use in simulations 3:44-45

Genetics, simulation 3:58-59
Graphics
  dissociation curves and 1:58
  from HUMAN model 2:30-32
  in radiology 1:30
  oriented database 4:54-56
  slides and 1:33
Group instruction 1:4-6, 1:9-11, 1:17-19, 1:29-32, 1:33-36, 1:57-62, 2:35-38, 2:92-94, 4:17-20, 4:33-35, 4:73-76

Hardware
  access to 2:33-35
  for arm anatomy 2:14-16
  authoring systems and 2:6
  for interfacing 2:61
  for oscilloscope substitution 2:81-82
  for physiology lab 1:20
Health care 1:65
Health Education Network 2:89
Hematology, videodisc 4:12-15
Hemolysis 5:26-27
Hodgkin-Huxley
  model 2:26-29
  squid axon simulation 1:5
HUMAN model 2:29-32, 2:41-43
HyperCard 5:33-34
Hypertext 5:33-34

IBM-PC, Apple II program conversion 3:49-52
Immunology 1:39
Input-output design 1:57
Information systems 3:33-36
Intelligent computer-aided instruction (ICAI) 5:86-88
Interactive video
  approach to program development 3:9-12
  conversion of videotape 3:27-30
  in hematology 4:12-15
  in medical education 4:65-68
  signal processing 3:12-15
Interactive video system 1:49
Interface, photosensitive 5:25-28
Interfacing 2:59-61
  laboratory/lecture 3:67-68

JANUS, interface between laboratory and lecture 3:67-68

Keeping Abreast of the Literature 1:23-24, 1:47, 1:69-70, 2:22-23, 2:48, 2:71-72, 2:94-95, 3:22-23, 3:46-47, 3:70-71, 3:93-94, 4:23, 4:47, 4:69-71, 4:93-94, 5:23, 5:47-48, 5:76, 5:89-90

Laboratories, lessons from 5:5-8
Laboratory
  data acquisition in 1:19, 5:2-3
  exercises 4:25-30, 4:49-53, 4:57-60, 4:60-63
  microcomputer 3:67-68
  physiology 5:25-28
  photosensitive interface in 5:25-28
  simulated microbiology 3:57-59
Laboratory/lecture interface 3:67-68
Languages 4:14, 4:20-22
  authoring 2:3-4
  graphic simulation, 7:49-56, 9:65-71
Learning center 4:89-91
Lectures, computer use in 1:9, 1:59, 4:73-78
Liquid crystal display projectors 4:76-77
Lung sounds 1:49

Macintosh 4:54-56, 5:33-35, 5:49-56, 5:65-71, 5:75-76
MacPILOT 3:38-39
Magnetic resonance imaging 1:29
Mastery oriented teaching unit 3:66-67
Mathematical models 1:13
MENTOR, program to teach differential diagnosis process 3:52-55
Microbiology, simulated laboratory in 3:57-59, 4:28
Microbiology-Immunology Test Item bank 1:39
Microcomputer center 3:76-79
Microcomputer laboratory 3:67-68
Microcomputers
  interfacing to 2:59-61
  in nursing 2:67-71
  simulations on 2:35-38
  video images on 2:77-79
Models, *see also* simulations
  HUMAN 2:29-32, 2:41-43
  nerve 2:26-29, 2:82-85
  pulse pressure 5:51-54
  structure of 1:13
  TIME 2:92-94
Multiple choice questions 1:15, 2:62, 2:86-87
Multiuser system 1:20
Muscle physiology 4:57-60, 4:73-76, 4:85

National Resource for Computers in Life Science Education 2:91, 3:1-5
  annual report 5:9-10
  software evaluation program 5:73-75
  questionnaire 3:7, 4:87
Nerve conduction velocity 2:82-85
Networking, national 1:41
Neuroscience Software Project 1:9
NRCLSE *see* National Resource for Computers in Life Science Education
Nuclear medicine 4:26-27, 5:57-60
Nursing 1:67, 2:67-71
  skills simulation 4:26-27

Optical videodiscs 1:25
Oscilloscopes 2:81-82
Osmotic pressure 1:34
Oxygen transport 1:58

Pathology 4:12-15, 4:65-68
Patient simulation 2:92-94
PC/PILOT 3:38
Peer critique 4:68-69, 4:91-92, 5:73-75
Peer review 4:68-69, 4:91-92
Photosynthesis 5:3
Physiology 1:4, 1:36, 4:27-30, 4:54-56, 4:61, 4:73-76
  cardiovascular 4:49-53, 5:5-6, 5:50-56, 5:86
  comparative 1:54
  HUMAN model of 2:29-32, 2:41-43
  laboratory data acquistion and 1:19
  muscle 4:57-60, 5:27
  plant 5:1-4
  respiratory 4:28, 5:6-8, 5:27-28
  simulations 5:49-56
  undergraduate 5:25-28
Pictures, storage of 1:26

0742-3233/88/$0.00 + 2.00

PILOT 3:36-39, 3:55, 4:20-22
  sources of information 3:39
Plant physiology 5:1-4
Polygraphs 2:81-86
Problem sets 1:2
PRODUCER 4:14
Programmed learning material 1:2
Programs, *see also* software
  guidelines for 1:22
  preparation time for 1:35
Projection monitors 1:17, 4:76-77
Pulse pressure, model 5:51-54

Radiology 1:29
Red blood cell hemolysis 5:26-27
Remedial education, in biology 2:17-22
Renal glomerular circulation 1:34
Respiratory physiology 4:28, 5:6-8, 5:27-28

Simulation 1:2, 2:62, 4:25-30
  approaches for teaching 3:41-45
  approaches in designing 3:74
  as a substitute for labs 3:59
  biological systems 1:11-14
  biology experiments 3:57-59, 4:60-63
  cardiovascular system 3:62-63, 4:49-53
  clinical 1:14
  design issues 3:73-76
  of experiments 2:76-77, 4:57-60, 4:60-63
  laboratory 5:57-60
  language 5:49-56, 5:65-71
  as lecture aids 2:35-38
  in microbiology 3:57-59
  of muscle 4:57-60
  nursing skills 4:26-27
  patient 2:92-94, 3:63
  physiology 3:62-63
  respiratory system 3:4, 4:28
  wildlife management 5:66-70
Slides, graphics in lieu of 1:33
Smart tutors 3:19-22, 5:86-88
Software 1:62
  authoring systems 5:81-85
  available 2:23-24, 2:49-56, 4:36-39, 4:41-45, 5:35-39, 5:45-46
  copyright of 2:57-59
  creation of 2:1-7
  evaluation forms 5:77-79
  evaluation of 1:51, 2:11-14, 2:70-71, 4:68-69, 4:91-92
  evaluation program 5:73-75
  expert systems 5:43-44
  graphics 1:30
  HyperCard 5:33-34
  interfacing and 2:60-61
  LabView 5:49-56
  peer critique of 5:73-75
  for physiology lab 1:21
  simulation 5:49-56, 5:57-60, 5:65-71
  sources of 2:23-24, 3:62-63, 4:36-39, 4:41-45, 5:39, 5:46-47, 5:49, 5:56
  STELLA 5:65-71
Sony projection monitor 1:18
Sophie, smart tutor 3:21
Sound in instruction 1:50
STELLA simulation software 5:65-71
Student laboratories 4:25-30, 4:49-53, 4:57-60, 4:60-63
Students 2:66-67
  affective teaching of 2:9-11
  interactions with 2:13
  view of computer-based curriculum 5:75-76
SuperPILOT 3:38, 4:14, 4:20-22
Systems ecology 4:9-12

Tabular data 1:60
Teaching at a remote site 4:33-35
Telecommunications 1:42
Teleconferencing 4:33-35
TIME project 2:92-94
Tutorials, in basic science education 3:25-27

Veterinary curriculum 5:75-76
Video signals and devices 3:12-15
  composite signals 3:14-15
  RGB signals 3:15
Video workstation 4:65-68
Videocamera, with interactive videotape 3:29
Videodisc 1:25, 2:43-45, 2:92
  development 4:13-14
  generic 2:73-76
  hardware selection 4:14, 4:65-68
  language selection 4:14
Videotape
  conversion 3:27-30
  use with interactive video 3:9-12
Voltage clamping 1:5

Well counter simulation 5:57-60
Wildlife management 4:20-22, 5:66-70

A limited number of volumes 1,2,3, and 4 of CLSE are available for purchase. The cost per volume is $30.00 (US) plus shipping. Address orders to:

NRCLSE, Mail Stop RC-70
University of Washington
Seattle, WA 98195

0742-3233/88/$0.00 + 2.00

AIMS AND SCOPE

The goal of *Computers in Life Science Education* is to provide a means of communication among life science educators who anticipate or are currently employing the computer as an educational tool. The range of content includes, but is not limited to, articles focusing on computer applications and their underlying philosophy, reports on faculty/student experiences with computers in teaching environments, and software/hardware reviews in both basic science and clinical education settings.

INVITATION TO CONTRIBUTORS

Articles consistent with the goals of *Computers in Life Science Education* are invited for possible publication in the newsletter.

PREPARATION AND SUBMISSION OF MATERIAL

Articles submitted for publication should not exceed 2000 words and should be typewritten, double spaced, with wide margins. The original and two copies including two sets of figures and tables should be sent to the Editor: Dr. Harold Modell, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

Title page should include full title, list of authors, academic or professional affiliations, and complete address and phone number of the corresponding author.

Illustrations should be submitted as original drawings in India ink or sharp, unmounted photographs on glossy paper. The lettering should be such that it can be legible after reduction (width of one column = 5.7 cm).

Reference style and form should follow the "number system with references alphabetized" described in the Council of Biology Editors Style Manual. References should be listed in alphabetical order by the first author's last name, numbered consecutively, and cited in the text by these numbers.

RESPONSIBILITY AND COPYRIGHT

Authors are responsible for accuracy of statements and opinions expressed in articles. All authors submitting manuscripts will be sent a copyright transfer form to complete. The completed form must be returned before the work will be published.

SUBSCRIPTION INFORMATION

Computers in Life Science Education is published monthly by National Resource for Computers in Life Science Education, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Subscription rate is $40.00 for 12 issues, including postage and handling in the United States and Canada. Add $20.00 for postage (airmail) in Mexico and Europe and $23.00 for the rest of the world.

This newsletter has been registered with the Copyright Clearance Center, Inc. Consent is given for copying of articles for personal or internal use, or for the personal or internal use of specific clients. This consent is given on the condition that the copier pay through the Center the per-copy fee stated in the code on the first page for copying beyond that permitted by the US Copyright Law. If no code appears on an article, the author has not given broad consent to copy and permission to copy must be obtained directly from the author. This consent does not extend to other kinds of copying, such as for general distribution, resale, advertising and promotional purposes, or for creating new collective works.

Address orders, changes of address, and claims for missing issues to NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. Claims for missing issues can be honored only up to three months for domestic addresses and six months for foreign addresses. Duplicate copies will not be sent to replace ones undelivered due to failure to notify NRCLSE of change of address.

Address editorial correspondence to Harold I. Modell, PhD, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195. (BITNET MODELL@UWALOCKE)

POSTMASTER: Send address changes to *Computers in Life Science Education*, NRCLSE, Mail Stop RC-70, University of Washington, Seattle, WA 98195.

0742-3233/88/$0.00 + 2.00